4. WATER QUALITY ASSESSMENT

4.1 Introduction

EPA based the methodologies for assessing both surface and pore water quality impacts from the discharge of SBF-cuttings on the methodologies used to assess the discharge of water-based fluids (WBFs) and associated cuttings (WBF-cuttings) for the offshore effluent limitations guidelines (ELG). The methodology for the offshore guidelines is presented in Avanti Corporation, 1993. However, there are several major differences in the analyses, most notably the absence of bulk drilling fluid discharges in the SBF guidelines. In the offshore ELG, these bulk discharges were a major wastestream and numerous existing drilling fluid characterization and transport studies were used as sources of data for the water quality assessment. In the current SBF-cuttings discharge impact analysis, surface water quality assessments rely on modeling data presented in a study (Brandsma, 1996) of the post-discharge transport behavior of oil and solids from cuttings contaminated with oil-based fluids (OBF-cuttings). Due to the similar hydrophobic and physical properties between SBFs and OBFs, EPA assumes that dispersion behavior of SBF-cuttings is similar to that of OBF-cuttings.

In addition, the offshore ELG only examined impacts in the Gulf of Mexico. For the SBF guidelines, EPA considered the impacts in offshore California and Cook Inlet, Alaska separately from the Gulf of Mexico. Although the analysis methodology does not change between regions, data used to conduct the water quality assessment contains certain assumptions specific to each region, for example, current speed.

For the pore water quality assessment, the absence of bulk drilling fluid discharges greatly affects the annual pollutant loadings. EPA applied the same methodology used for the offshore ELG in assessing the effects of SBF-cuttings discharges on pore water quality for the current industry practice and the discharge option.

The analyses in this chapter are conservative due to the assumption that discharged pollutants immediately leach into the water column or into the pore water. In the water column, total organic pollutant discharge concentrations are assumed to represent the soluble concentration. Metals are assumed to leach immediately into the water column at pollutant-specific amounts determined for mean seawater pH (as derived in Avanti Corporation, 1993; Appendix C). In the pore water, pollutant-specific partition coefficients are used for organic pollutants (from EPA's IRIS) to determine soluble concentrations. The mean seawater leach factors are used for metals in the same manner as used for the water column concentrations. For both organic pollutants and metals, the total leached concentration is assumed to be immediately available in the pore water.

In general, the methodology consists of modeling incremental water column and pore water concentrations and comparing them to EPA water quality criteria/toxic values for marine acute, marine chronic, and human health protection. Additionally, EPA used the proposed sediment guidelines for protection of benthic organisms to assess potential impacts from a group of select metals in pore water (EPA, 1998b). Note that all of these comparisons are performed only for those pollutants for which EPA has numeric criteria. Those pollutants include priority and nonconventional pollutants associated with the drilling fluid barite and with contamination by formation (crude) oil, but do *not* include synthetic base fluids themselves. Potential impacts from synthetic base fluid compounds are described in Chapters 6 through 9 of this document.

4.2 Surface Water

To help evaluate the relative water quality impacts of the current industry practice and regulatory options, EPA estimates the water column concentration of pollutants present in SBF drilling discharges under regulatory discharge options and compares them to Federal water quality criteria/toxic values. This comparative analysis applies only to those pollutants for which EPA has published numeric criteria, as presented in Exhibit 4-1.[1] Note that there are no criteria for the synthetic-based fluid compounds themselves.

In order to determine the water column pollutant concentrations, EPA used data regarding the transport of discharged drill solids and corresponding oil concentration in the water column. The study was performed by Brandsma (1996) and the data are published in the April 1996 E&P Forum Summary Report No. 2.61/202. Because of the extensive North Sea use of oil-based drilling fluids (OBF) and discharge of OBF-cuttings, the E&P Forum sponsored the research project to evaluate the modeled dispersement of treated versus untreated OBF-cuttings. Following is a description of the Brandsma (1996) study from that E&P report.

Brandsma modeled the discharge of nine treatments of cuttings obtained from a North Sea drilling platform to obtain: (1) a maximum deposition density (g/m^2) of cuttings and oil; (2)

[1] Subsequent to finalization of the analyses contained in this chapter, EPA published revised water quality criteria (63 FR 68354, December 10, 1998). The following changes affect this Environmental Assessment water quality analyses and will be reflected in the final rule: arsenic human health criterion is deleted; copper acute criterion is raised to 4.8 ug/l and copper chronic criterion is raised to 3.1 ug/l; mercury chronic criterion is raised to 0.94 ug/l and mercury human health is reduced to 0.051 ug/l; and phenol human health criterion is deleted. Appendix B contains the December 1998 criteria recommendations and an analysis of how the water quality assessment would change using these revised criteria.

water column concentrations of suspended solids and oil; (3) the maximum thickness (cm) of cuttings deposited on the seabed; and (4) the seabed area (ha) that would achieve a 100 ppm oil content threshold in the upper 4 cm or 10 cm of the sediment.

Exhibit 4-1. Federal Water Quality Criteria

Pollutant	Marine Acute Criteria (μg/l)	Marine Chronic Criteria (μg/l)	Human Health Criteria (μg/l) (a)
Antimony			4,300
Arsenic	69	36	0.14
Cadmium	42	9.3	
Chromium (VI)	1,100	50	
Copper	2.4	2.4	
Lead	210	8.1	
Mercury	1.8	0.025	0.15
Nickel	74	8.2	4,600
Phenol			4,600,000
Selenium	290	71	
Silver	1.9		
Thallium			6.3
Zinc	90	81	

(a) Human health criteria for consumption of organisms only; risk factor of 10^{-6} for carcinogens.
Source: Tabulation of water quality criteria, EPA Health and Ecological Criteria Division, February 1997. See footnote 1 (page 4-2) and Appendix B for information on criteria revision as of December 10, 1998.

The treatment technologies included: (1) no treatment (lab formulated control), (2) untreated cuttings from shale shakers, (3) centrifugation, (4) solvent extraction, (5) thermal treatment, and (6) water washing. The bulk densities of the cutting ranged from 1,830 g/l to 2,430 g/l; oil content for the six types of cuttings ranged from 0.02% (dry weight basis) to 19.6%.

The author simulated four sites in the North Sea: Southern (30 m water depth and depth-averaged, root mean-squared current speed of 0.37 m/s); Central (100 m water depth and current speed of 0.26 m/s); Northern (150 m water depth and current speed of 0.22 m/s); and Haltenbanken (250 m water depth and current speed of 0.10 m/s).

The Offshore Operators Committee (OOC) drilling and production discharge model was used to simulate the concentrations and deposition of discharged cuttings. The OOC model utilized a mixture of 12 profile size classes of mud and cuttings particles (with adsorbed oil) and water. All other discharge conditions were fixed. All discharges simulated a 68.5-hour discharge of 152 m^3 of cuttings from a 0.3 m diameter pipe shunted to a depth of 15.2 m below mean sea level. This cuttings volume is the volume expected from a single well section of OBF-cuttings. Results presented are based on these 152 m^3 model efforts, however, results are scaled up to a 300 m^3 volume which was later determined by the project steering committee to be more representative of actual OBF-cuttings volumes generated using OBFs (representing two well sections).

Hydrographic conditions were conservatively selected to maximize predicted cuttings deposition on the seabed by choosing the minimum water column stratification at each site. The result is no density gradient at all sites but the Haltenbanken site, which exhibited only a weak (0.0016 $kg/m^3/m$) gradient.

Water column results were determined at a radial distance of 1000 m downstream. For untreated and centrifuged OBF-cuttings, projected water column oil concentrations at 1000 m were below maximum North Sea background levels at all four sites; all other treatments resulted in projected 1000 m oil concentrations that exceeded maximum background levels (except through treatment at the Haltenbanken site). The explanation for this apparent conundrum is that while treatments other than centrifugation also reduce oil content (from an untreated level of 15.8% [w/w] to a range of 0.3% to 5.1%), these treatments also generate cuttings with finer particle sizes. Thus, according to the model, the untreated and centrifuged OBF-cuttings would not reach the 1000 m mark to the same extent that the treated OBF-cuttings would because the finer particles created by the treatment have lower settling velocities and are transported farther in the water column (Brandsma, 1996).

Although Brandsma (1996) does not present oil concentration data for a radial distance of 100 m (the edge of the mixing zone established for U.S. offshore discharges by Clean Water Act Section 403, Ocean Discharge Criteria, as codified at 40 CFR 125 Subpart M), the study does present data on suspended solids and oil concentration as a function of transport time. Using current speeds representative of each geographic area (Gulf of Mexico; Cook Inlet, Alaska; and offshore California) and the transport times reported by Brandsma, EPA derived the corresponding oil concentrations and dilutions at 100 m. For example, assuming a mean current speed of 15 cm/s as representative of the Gulf of Mexico, a transport time of approximately 11 minutes is derived as the time required for the plume to reach 100 m (100 m/0.15 m/sec). From graphical analysis of the data presented in Figure 2 of Brandsma's 1996 study (provided in Appendix C), the oil concentration can be determined for selected transport times. Based on the mean initial oil concentration of the 9 cuttings cases presented in the study (5.5% in water-washed cuttings), the dilutions achieved can be estimated for a selected time (i.e., distance) in the following manner. The 5.5% (w/w) oil content converts to 55 g oil/kg wet cuttings. Based on a reported mean OBF-cuttings density of 2.050 kg wet cuttings/l, the initial oil concentration of 112,750 mg oil/l (55 g/kg x 2.050 kg/l) is used to determine the dilutions achieved. For the Gulf of Mexico example, the oil concentration at 11 minutes of 3.2 mg/l is used to calculate a 35,234-fold dilution (112,750 mg/3.2 mg) at 11 minutes. As described above, 11 minutes represents the estimated time at which the plume would reach the edge of the mixing zone at 100 meters.

Projected water column pollutant concentrations at the edge of a 100-m mixing zone are calculated by dividing the drilling waste pollutant concentration by the dilutions available. The effluent concentrations for metals are further adjusted by a leach factor to account for the portion of the total metal pollutant concentration that is dissolved and therefore available in the water column. In terms of metal concentrations, this analysis is conservative in that it assumes that all leachable metals are immediately leached into the water column.

Exhibit 4-2 summarizes the water quality analyses for Gulf of Mexico, Cook Inlet, Alaska, and offshore California water column pollutant concentrations at 100 m from SBF-cuttings discharges. The results show that no exceedances of any Federal or state water quality criteria or standards are expected using current technology or the discharge option.

Exhibit 4-2. Summary of Water Column Water Quality Analyses

Discharge Region	Shallow Water				Deep Water			
	Development		Exploratory		Development		Exploratory	
	Current Technology	Discharge Option	Current Technology	Discharge Option	Current Technology	Discharge Option	Current Technology	Discharge Option
Gulf of Mexico	-- (b)	--	--	--	--	--	--	--
California	--	--	NA (c)	NA	--	--	NA	NA
Cook Inlet, Alaska	--	–	NA	NA	NA	NA	NA	NA

(a) Current technology equals the Gulf of Mexico current industry practice of SBF-cuttings treatment to 11% SBF retention on cuttings.

(b) -- indicates no exceedances of Federal or state water quality criteria or standards from any of the discharged pollutants.

(c) NA = Not applicable; For Cook Inlet, Alaska and offshore California, EPA does not anticipate any exploratory drilling to occur. In addition, EPA does not consider any of the drilling activity in Cook Inlet, Alaska to be in deep water (> 1,000 ft).

4.2.1 *Gulf of Mexico*

Exhibits 4-3 and 4-4 compare the projected pollutant concentrations for Gulf of Mexico discharges of SBFs with the Federal water quality criteria under the discharge scenarios for the current technology and the discharge option. For this analysis, and all subsequent water quality and pore water quality analyses in this report, the zero discharge option is not presented in tabular form. Because no drilling wastes are discharged under the zero discharge option, there are no water quality criteria concerns to assess.

The water column pollutant concentrations for all four model wells (deep water exploratory, deep water development, shallow water exploratory, and shallow water development) are the same within each discharge scenario. This occurs because only the total discharge volume for each of the model wells varies, not the discharge rate or individual pollutant concentrations. The reader should also note that in the exhibits that follow, only the most stringent water quality criterion is listed for each pollutant. Any exceedances of water quality criteria are detailed in the footnotes of each table.

When comparing the Federal water quality criteria to the SBF concentration in the water column at 100 meters from the discharge, no exceedances of any of the Federal water quality criteria occurred for any model wells in the Gulf of Mexico using the current technology, nor under either the discharge or zero discharge options.

4.2.2 *Cook Inlet, Alaska*

EPA compared pollutant concentrations resulting from the discharge of SBF-cuttings in Cook Inlet, Alaska to both Federal criteria and state water quality standards because the discharges occur in state waters. The Alaska standard for “toxic and other deleterious organic and inorganic substances” states that “individual substances may not exceed criteria in EPA, Quality Criteria for Water, or, if those do not exist, may not exceed the Primary Maximum Contaminant Levels of the Alaska Drinking Water Standards (18 AAC 80).” The Alaska standards for waters classified as marine waters for growth and propagation of fish, shellfish, and other aquatic life, and wildlife are presented in Exhibit 4-5.

Exhibit 4-3. Water Column Pollutant Concentrations - Gulf of Mexico, Current Technology

Pollutant	Pollutant Conc. in Effluent (mg/l) (a)	Trace Metal Leach Factor (b)	Water Column Conc. at 100 m (mg/l) (c)	Federal Water Quality Criteria (mg/l) (d)	Federal Criteria Exceedance Factor (e)
Naphthalene	1.1700		3.32e-05		
Fluorene	0.6382		1.81e-05	1.40e+01	
Phenanthrene	1.5136		4.30e-05		
Phenol	0.0001		2.39e-09	4.60e+03	
Cadmium	0.1707	0.1100	5.33e-07	9.30e-03	
Mercury	0.0155	0.0180	7.93e-09	2.50e-05	
Antimony	0.8843			4.30e+00	
Arsenic	1.1015	0.0050	1.56e-07	1.40e-04	
Beryllium	0.1086				
Chromium	37.2331	0.0340	3.59e-05	5.00e-02	
Copper	2.9011	0.0063	5.19e-07	2.40e-03	
Lead	5.4453	0.0200	3.09e-06	8.10e-03	
Nickel	2.0944	0.0430	2.56e-06	8.20e-03	
Selenium	0.1707			7.10e-02	
Silver	0.1086			1.90e-03	
Thallium	0.1862			6.30e-03	
Zinc	31.1051	0.0041	3.92e-06	8.10e-02	
Aluminum	1,407.0				
Barium	18,616.5	0.0021	1.11e-03		
Iron	2,380.5	0.1300	8.78e-03		
Tin	2.2650				
Titanium	13.5746				
Alkylated benzenes	6.5861		1.87e-04		
Alkylated naphthalenes	61.9177		1.76e-03		
Alkylated fluorenes	7.4534		2.12e-04		
Alkylated phenanthrenes	9.4169		2.67e-04		
Alkylated phenols	0.0007		2.10e-08		
Total biphenyls	12.2395		3.47e-04		
Total dibenzothiophenes	0.0107		3.02e-07		

(a) See section 3.2 for effluent pollutant concentrations.
(b) Source: Offshore Environmental Assessment (Avanti, 1993); assumed to be 1 unless otherwise listed.
(c) Water column pollutant conc. = (avg. poll. conc. x leach factor)/dilutions (35,234 dilutions).
(d) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.
(e) No Federal water quality criteria are exceeded.

Exhibit 4-4. Water Column Pollutant Concentrations - Gulf of Mexico, Discharge Option

Pollutant	Pollutant Conc. in Effluent (mg/l) (a)	Trace Metal Leach Factor (b)	Water Column Conc. at 100 m (mg/l) (c)	Federal Water Quality Criteria (mg/l) (d)	Federal Criteria Exceedance Factor (e)
Naphthalene	0.811		2.30e-05		
Fluorene	0.442		1.26e-05	1.40e+01	
Phenanthrene	1.049		2.98e-05		
Phenol	0.0001		1.66e-09	4.60e+03	
Cadmium	0.118	0.1100	3.69e-07	9.30e-03	
Mercury	0.0108	0.0180	5.49e-09	2.50e-05	
Antimony	0.613			4.30e+00	
Arsenic	0.763	0.0050	1.08e-07	1.40e-04	
Beryllium	0.0750				
Chromium	25.80	0.0340	2.49e-05	5.00e-02	
Copper	2.011	0.0063	3.59e-07	2.40e-03	
Lead	3.774	0.0200	2.14e-06	8.10e-03	
Nickel	1.452	0.0430	1.77e-06	8.20e-03	
Selenium	0.118			7.10e-02	
Silver	0.0750			1.90e-03	
Thallium	0.129			6.30e-03	
Zinc	21.56	0.0041	2.51e-06	8.10e-02	
Aluminum	975.2				
Barium	12,902	0.0021	7.69e-04		
Iron	1,650	0.1300	6.09e-03		
Tin	1.570				
Titanium	9.408				
Alkylated benzenes	4.566		1.30e-04		
Alkylated naphthalenes	42.93		1.22e-03		
Alkylated fluorenes	5.167		1.47e-04		
Alkylated phenanthrenes	6.529		1.85e-04		
Alkylated phenols	0.0005		1.46e-08		
Total biphenyls	8.486		2.41e-04		
Total dibenzothiophenes	0.0074		2.10e-07		

(a) See section 3.2 for effluent pollutant concentrations.
(b) Source: Offshore Environmental Assessment (Avanti, 1993); assumed to be 1 unless otherwise listed.
(c) Water column pollutant conc. = (avg. poll. conc. x leach factor)/dilutions (35,234 dilutions).
(d) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.
(e) No Federal water quality criteria are exceeded.

Exhibit 4-5. Alaska State Water Quality Standards

Pollutant	Standard (mg/l)
Antimony	6.00E-03
Barium	2.00E+00
Beryllium	4.00E-03
Chromium	1.00E-01
Nickel	1.00E-01
Selenium	5.00E-02
Thallium	2.00E-03

EPA determined the dilutions for assessment of compliance with water quality criteria and standards using the same methodology as for the Gulf of Mexico analysis. A current speed of 40 cm/sec was used (EPA Region 10, 1984), resulting in a transport time of 4.2 minutes to reach the edge of the 100-meter mixing zone. The midpoint oil concentration from Brandsma (1996) at 4 minutes is 28 mg/l. This concentration is a 4,027-fold dilution from the initial discharge concentration of oil (112,750 mg/l).

The current operating practice in Cook Inlet, Alaska is zero discharge of SBF-cuttings. However, for the purpose of comparison with the discharge option, an analysis of the current technology (11% SBF retention on cuttings) is presented in Exhibit 4-6 for Cook Inlet, Alaska. For the discharge option, Exhibit 4-7 presents the water column concentrations of pollutants at 100 meters from the discharge point and compares them to Federal water quality criteria and Alaska state standards. Under the current technology and the discharge option, there are no exceedances of the Federal criteria or state numerical standards in Cook Inlet, Alaska.

4.2.3 *Offshore California*

EPA compared pollutant concentrations resulting from the discharge of SBF-cuttings in offshore California waters to Federal water quality criteria to determine compliance with these guidelines. EPA determined the dilutions for assessment of compliance with water quality standards using the same methodology as for the Gulf of Mexico analysis. A current speed of 30 cm/sec was used (MMS, 1985), resulting in a transport time of 5.5 minutes to reach the edge of the 100-meter mixing zone. The midpoint oil concentration from Brandsma (1996) at 5 minutes is 20 mg/l. This concentration is a 5,638-fold dilution from the initial discharge concentration of oil (112,750 mg/l).

Exhibit 4-6. Water Column Pollutant Concentrations - Cook Inlet, Alaska, Current Technology

Pollutant	Pollutant Conc. in Effluent (mg/l) (a)	Trace Metal Leach Factor (b)	Water Column Conc. at 100 m (mg/l) (c)	Federal Water Quality Criteria (mg/l) (d)	State Water Quality Standards (mg/l)	Criteria/ Standards Exceed. Factor (e)
Naphthalene	1.1700		2.91e-04			
Fluorene	0.6382		1.58e-04	1.40e+01		
Phenanthrene	1.5136		3.76e-04			
Phenol	0.0001		2.09e-08	4.60e+03		
Cadmium	0.1707	0.1100	4.66e-06	9.30e-03		
Mercury	0.0155	0.0180	6.93e-08	2.50e-05		
Antimony	0.8843		2.20e-04	4.30e+00	6.00e-03	
Arsenic	1.1015	0.0050	1.37e-06	1.40e-04	5.00e-01	
Beryllium	0.1086		2.70e-05		4.00e-03	
Chromium	37.2331	0.0340	3.14e-04	5.00e-02	1.00e-01	
Copper	2.9011	0.0063	4.54e-06	2.40e-03		
Lead	5.4453	0.0200	2.70e-05	8.10e-03		
Nickel	2.0944	0.0430	2.24e-05	8.20e-03	1.00e-01	
Selenium	0.1707		4.24e-05	7.10e-02	5.00e-02	
Silver	0.1086		2.70e-05	1.90e-03		
Thallium	0.1862		4.62e-05	6.30e-03	2.00e-03	
Zinc	31.1051	0.0041	3.17e-05	8.10e-02		
Aluminum	1,407.0					
Barium	18,616.5	0.0021	9.71e-03		2.00e+00	
Iron	2,380.5	0.1300	7.68e-02			
Tin	2.2650		5.62e-04			
Titanium	13.5746		3.37e-03			
Alkylated benzenes	6.5861		1.64e-03			
Alkylated naphthalenes	61.9177		1.54e-02			
Alkylated fluorenes	7.4534		1.85e-03			
Alkylated phenanthrenes	9.4169		2.34e-03			
Alkylated phenols	0.0007		1.84e-07			
Total biphenyls	12.2395		3.04e-03			
Total dibenzothiophenes	0.0107		2.64e-06			

(a) See section 3.2 for effluent pollutant concentrations.
(b) Source: Offshore Environmental Assessment (Avanti, 1993); assumed to be 1 unless otherwise listed.
(c) Water column pollutant conc. = (avg. poll. conc. x leach factor)/dilutions (4,027 dilutions).
(d) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.
(e) No Federal water quality criteria or state standards are exceeded.

Exhibit 4-7. Water Column Pollutant Concentrations - Cook Inlet, Alaska, Discharge Option

Pollutant	Poll. Conc. in Effluent (mg/l) (a)	Trace Metal Leach Factor (b)	Water Column Conc. at 100 m (mg/l) (c)	Federal Water Quality Criteria (mg/l) (d)	State Water Quality Standards (mg/l)	Criteria/ Standards Exceed. Factor (e)
Naphthalene	0.811		2.01e-04			
Fluorene	0.442		1.10e-04	1.40e+01		
Phenanthrene	1.049		2.61e-04			
Phenol	0.0001		1.45e-08	4.60e+03		
Cadmium	0.118	0.1100	3.23e-06	9.30e-03		
Mercury	0.0108	0.0180	4.81e-08	2.50e-05		
Antimony	0.613		1.52e-04	4.30e+00	6.00e-03	
Arsenic	0.763	0.0050	9.48e-07	1.40e-04	5.00e-01	
Beryllium	0.075		1.87e-05		4.00e-03	
Chromium	25.80	0.0340	2.18e-04	5.00e-02	1.00e-01	
Copper	2.011	0.0063	3.15e-06	2.40e-03		
Lead	3.774	0.0200	1.87e-05	8.10e-03		
Nickel	1.452	0.0430	1.55e-05	8.20e-03	1.00e-01	
Selenium	0.118		2.94e-05	7.10e-02	5.00e-02	
Silver	0.075		1.87e-05	1.90e-03		
Thallium	0.129		3.20e-05	6.30e-03	2.00e-03	
Zinc	21.56	0.0041	2.19e-05	8.10e-02		
Aluminum	975.2					
Barium	12,902	0.0021	6.73e-03		2.00e+00	
Iron	1,650	0.1300	5.33e-02			
Tin	1.570		3.90e-04			
Titanium	9.408		2.34e-03			
Alkylated benzenes	4.566		1.13e-03			
Alkylated naphthalenes	42.93		1.07e-02			
Alkylated fluorenes	5.167		1.28e-03			
Alkylated phenanthrenes	6.529		1.62e-03			
Alkylated phenols	0.0005		1.28e-07			
Total biphenyls	8.486		2.11e-03			
Total dibenzothiophenes	0.0074		1.83e-06			

(a) See section 3.2 for effluent pollutant concentrations.
(b) Source: Offshore Environmental Assessment (Avanti, 1993); assumed to be 1 unless otherwise listed.
(c) Water column pollutant conc. = (avg. poll. conc. x leach factor)/dilutions (4,027 dilutions).
(d) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.
(e) No Federal water quality criteria or state standards are exceeded.

The current practice in offshore California is zero discharge of SBF-cuttings. However, for the purpose of comparison with the discharge option, an analysis of the current technology (11% SBF retention on cuttings) is presented in Exhibit 4-8 for offshore California. For the discharge option, Exhibit 4-9 presents the water column concentrations of pollutants at 100 meters from the discharge point and compares them to Federal water quality criteria. Under both current technology and the discharge option, there are no exceedances of the Federal water quality criteria in offshore California.

4.3 Sediment Pore Water Quality

EPA calculated sediment pollutant levels based on the assumption of a uniform distribution of the annual mass loadings of pollutants from model operations into a defined area of impact. Using the derived sediment pollutant concentrations, EPA assessed sediment pore water quality. A summary of the pore water quality analyses for discharges of SBF-cuttings in the Gulf of Mexico, Cook Inlet, Alaska, and offshore California is presented in Exhibit 4-10.

4.3.1 *Gulf of Mexico*

To assess the pore water quality impacts of the discharge of SBF-cuttings on the benthic environment, EPA determined the pollutant concentrations in the pore water for each model well and each discharge scenario at the edge of the 100-meter mixing zone. EPA then compared these projected pore water concentrations of pollutants from the SBF-cuttings to Federal water quality criteria to determine the number of exceedances and the magnitude of each exceedance. Following is a detailed explanation of the methodology used to assess pore water quality.

The pore water quality analysis of the offshore Effluent Limitations Guidelines characterized sediment pollutants through a number of field surveys of both exploratory and development operations. These surveys predominantly measured sediment barium content, which was considered the best marker for assessing transport and fate of the particulate fraction of water-based drilling fluids. In this current environmental assessment, EPA again assessed field surveys but the sediment concentration of synthetic base fluid was considered the most reliable marker of SBF-cuttings transport. EPA compiled sediment synthetic base fluid concentration data from 5 surveys of 11 wells. Ten wells were drilled in the North Sea and one in the Gulf of Mexico. If the survey data did not include data for a 100-m sampling location, EPA linearly extrapolated the existing data points to 100 m. A summary of the 100-m sediment synthetic base fluid concentrations is presented in Exhibit 4-11. For three of the wells listed in the summary, data for two different sampling transects are included. Because concentrations were averaged over different transects per well, that is, not consistently down current, the

Exhibit 4-8. Water Column Pollutant Concentrations - Offshore California, Current Technology

Pollutant	Pollutant Conc. in Effluent (mg/l) (a)	Trace Metal Leach Factor (b)	Water Column Conc. at 100 m (mg/l) (c)	Federal Water Quality Criteria (mg/l) (d)	Federal Criteria Exceedance Factor (e)
Naphthalene	1.1700		2.08e-04		
Fluorene	0.6382		1.13e-04	1.40e+01	
Phenanthrene	1.5136		2.68e-04		
Phenol	0.0001		1.48e-08	4.60e+03	
Cadmium	0.1707	0.1100	3.33e-06	9.30e-03	
Mercury	0.0155	0.0180	4.95e-08	2.50e-05	
Antimony	0.8843		1.57e-04	4.30e+00	
Arsenic	1.1015	0.0050	9.77e-07	1.40e-04	
Beryllium	0.1086		1.93e-05		
Chromium	37.2331	0.0340	2.25e-04	5.00e-02	
Copper	2.9011	0.0063	3.24e-06	2.40e-03	
Lead	5.4453	0.0200	1.93e-05	8.10e-03	
Nickel	2.0944	0.0430	1.60e-05	8.20e-03	
Selenium	0.1707		3.03e-05	7.10e-02	
Silver	0.1086		1.93e-05	1.90e-03	
Thallium	0.1862		3.30e-05	6.30e-03	
Zinc	31.1051	0.0041	2.26e-05	8.10e-02	
Aluminum	1,407.0				
Barium	18,616.5	0.0021	6.93e-03		
Iron	2,380.5	0.1300	5.49e-02		
Tin	2.2650		4.02e-04		
Titanium	13.5746		2.41e-03		
Alkylated benzenes	6.5861		1.17e-03		
Alkylated naphthalenes	61.9177		1.10e-02		
Alkylated fluorenes	7.4534		1.32e-03		
Alkylated phenanthrenes	9.4169		1.67e-03		
Alkylated phenols	0.0007		1.31e-07		
Total biphenyls	12.2395		2.17e-03		
Total dibenzothiophenes	0.0107		1.89e-06		

(a) See section 3.2 for effluent pollutant concentrations.
(b) Source: Offshore Environmental Assessment (Avanti, 1993); assumed to be 1 unless otherwise listed.
(c) Water column pollutant conc. = (avg. poll. conc. x leach factor)/dilutions (5,638 dilutions).
(d) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.
(e) No Federal water quality criteria are exceeded.

Exhibit 4-9. Water Column Pollutant Concentrations - Offshore California, Discharge Option

Pollutant	Pollutant Conc. in Effluent (mg/l) (a)	Trace Metal Leach Factor (b)	Water Column Conc. at 100 m (mg/l); (c)	Federal Water Quality Criteria (mg/l) (d)	Federal Criteria Exceedance Factor (e)
Naphthalene	0.811		1.44e-04		
Fluorene	0.442		7.85e-05	1.40e+01	
Phenanthrene	1.049		1.86e-04		
Phenol	0.0001		1.03e-08	4.60e+03	
Cadmium	0.118	0.1100	2.10e-05	9.30e-03	
Mercury	0.0108	0.0180	1.91e-06	2.50e-05	
Antimony	0.613		1.09e-04	4.30e+00	
Arsenic	0.763	0.0050	1.35e-04	1.40e-04	
Beryllium	0.075		1.33e-05		
Chromium	25.80	0.0340	4.58e-03	5.00e-02	
Copper	2.011	0.0063	3.57e-04	2.40e-03	
Lead	3.774	0.0200	6.69e-04	8.10e-03	
Nickel	1.452	0.0430	2.57e-04	8.20e-03	
Selenium	0.118		2.09e-05	7.10e-02	
Silver	0.075		1.33e-05	1.90e-03	
Thallium	0.129		2.29e-05	6.30e-03	
Zinc	21.56	0.0041	3.82e-03	8.10e-02	
Aluminum	975.2				
Barium	12,902	0.0021	4.81e-03		
Iron	1,650	0.1300	3.80e-02		
Tin	1.570		2.79e-04		
Titanium	9.408		1.67e-03		
Alkylated benzenes	4.566		8.10e-04		
Alkylated naphthalenes	42.93		7.61e-03		
Alkylated fluorenes	5.167		9.17e-04		
Alkylated phenanthrenes	6.529		1.16e-03		
Alkylated phenols	0.0005		9.12e-08		
Total biphenyls	8.486		1.51e-03		
Total dibenzothiophenes	0.0074		1.31e-06		

(a) See section 3.2 for effluent pollutant concentrations.
(b) Source: Offshore Environmental Assessment (Avanti, 1993).
(c) Water column pollutant conc. = (avg. poll. conc. x leach factor)/dilutions (5,638 dilutions).
(d) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.
(e) No Federal water quality criteria are exceeded.

Exhibit 4-10. Summary of Pore Water Quality Analyses - Factors by Which Criteria are Exceeded

Discharge Region	Pollutant	Shallow Water (a)				Deep Water (a)			
		Development		Exploratory		Development		Exploratory	
		Current Tech-nology	Discharge Option	Current Tech-nology	Discharge Option	Current Tech-nology	Discharge Option	Current Tech-nology	Discharge Option
Gulf of Mexico	Arsenic	1.3	-- (b)	2.7	--	1.9	1.1	4.3	2.5
	Chromium	--	--	1.7	--	1.3	--	2.8	1.6
	Mercury	--	--	--	--	--	--	1.2	--
	Lead	--	--	--	--	--	--	1.5	--
	Nickel	--	--	--	--	--	--	1.2	--
Cook Inlet, Alaska	Arsenic	--	--	NA (c)	NA	NA	NA	NA	NA
Offshore California	Arsenic	--	--	NA	NA	1.2	--	NA	NA

(a) There would be no exceedances for any pollutants with the zero discharge option.
(b) -- indicates that no exceedances are predicted.
(c) NA indicates that type of model well does not currently exist or is not projected for that geographic region.

resultant synthetic base fluid concentration represents the average concentration found at any given point 100 m around a well as opposed to the maximum (i.e., down current) concentration. Given the reported depths and discharge volumes of the studies, the calculated average concentration most closely represents current practice for a Gulf of Mexico shallow water exploratory model well.

In order to determine SBF-cuttings pollutant concentrations for other model well types, EPA assumed that the relative concentrations or proportions between the base fluid and other pollutants as found in the SBF are maintained after discharge and transport. Therefore, to project the sediment concentration of each pollutant, EPA multiplied the ratio of each pollutant to the synthetic base fluid by the average 100-m base fluid concentration (13,892 mg synthetic/kg for the shallow water exploratory model well; see Exhibit 4-11). For each model well, this factor is further adjusted to account for the varying total amount of oil (synthetic plus formation oil) discharged. For example, EPA determined that the shallow development well would discharge only 47.7% of the oil as the shallow exploratory well. Therefore, the sediment pollutant concentrations for the shallow development well are 47.7% of those for the shallow exploratory well. For the deep wells (using the shallow water exploratory well as 100%), these factors are 160.5% and 72.2% for exploratory and development well pollutants, respectively.

Exhibit 4-11. Summary of Synthetic Base Fluid Concentrations at 100 Meters

Data Source	Study Site/Location	Depth (m)	Base Fluid Type	Conc. at 100 m (mg/kg) (a)
Candler et al., 1995	MPI-895; Gulf of Mexico	39	PAO	90,105
Daan et al., 1996	K14-13; North Sea	30	Ester	522.1
Smith and May,1991 in Schaanning, 1995	Ula 7/12-9; North Sea	67	Ester	46,400
Baake et al., 1992 in Schaanning, 1995	Gyda 2/1-9; North Sea	--	Ether	1,418
Gjøs, 1995a in Vik et al., 1996a	Tordis Well; North Sea	181 - 218	PAO	15,090
Gjøs. 1995b in Vik et al., 1996a	Loke Well; North Sea	76 - 81	Ester	145.8
	Sleipner A Well; North Sea	76 - 81	Ester	62; 622
	Sleipner Ø Well; North Sea	--	Ester	3,850
Gjøs, 1992 & 1993 in Vik et al., 1996a	Gyda 2/1-9; North Sea	70	Ether	420; 200
Larsen, 1995 in Vik et al., 1996a	Ula 2/7-29; North Sea	67	Acetal	24,833; 10,000
Feldstedt, 1991 in Vik et al., 1996a	Ula 7/12-A6	67	Acetal	815
Average concentration at 100 meters (represents a Gulf of Mexico shallow water exploratory model well)				13,892
Average concentration at 100 meters (excluding the 2 shallowest discharges; represents Cook Inlet, Alaska and offshore California shallow water exploratory model well)				8,655

(a) More than one value per well represents values from different sampling transects.

These sediment pollutant concentrations are converted into pore water concentrations. For metals, the mean seawater leach factors of trace metals in barite are used. For organic pollutants, partition coefficients are used to project pore water concentrations. Partition coefficients estimate the ratio of sediment to pore water concentration as the product of the fraction of organic carbon (f_{oc}) and the octanol-water partition coefficient (K_{ow}). For sediments, the K_{ow} = the partition coefficient for organic particle carbon (K_{oc}). Therefore, $K_{sed} = f_{oc} * K_{oc}$. Both the f_{oc} and K_{oc} used for this analysis are presented in Exhibit 4-12 and are based on the offshore environmental analysis (Avanti Corporation, 1993). The leach factors and partition coefficients are summarized in Exhibit 4-12. The sediment concentration multiplied by the pollutant specific leach factor or inverse of the partition coefficient results in the amount of pollutant available in the pore water. To calculate the interstitial (pore water) concentration of each pollutant, the available pollutant sediment concentration is multiplied by the dry weight of sediment in a 1m x 1m x 0.05m unit volume and divided by the volume of water per unit volume of sediment. Based on the offshore Environmental Assessment, the dry weight of sediment equals 35.5 kg and the volume of pore water approximated from a dry sediment specific weight of 2 g/ml is 32.5 l (Avanti Corporation, 1993).

The calculated pore water concentrations of pollutants are then compared to their respective EPA marine water quality criteria to determine the nature and magnitude of any projected water quality exceedances. Exhibits 4-13 through 4-20 present the pore water quality analyses and comparisons to the EPA water quality criteria for Gulf of Mexico discharges from wells using the current and discharge option technologies.

4.3.2 *Cook Inlet, Alaska and Offshore California*

To assess the pore water quality impacts for Cook Inlet, Alaska and offshore California, EPA again used the synthetic base fluid concentrations presented in Exhibit 4-11 to estimate the concentration of synthetic fluids at 100 meters from the discharge. Due to the increased energy and depth of Cook Inlet and offshore California, two of the studies in Exhibit 4-11 were eliminated from the calculation of the average synthetic base fluid concentration at 100 meters. Both of the eliminated studies included discharges in less than 40 meters total water depth (Candler et al., 1995 and Daan et al., 1996).

Exhibit 4-12. Trace Metal Leach Factors and Organic Pollutant Partition Coefficients

Trace Metal	**Mean Seawater Leach Factor**		
Cadmium	0.11		
Mercury	0.018		
Arsenic	0.005		
Chromium	0.034		
Copper	0.0063		
Lead	0.02		
Nickel	0.043		
Zinc	0.0041		
Barium	0.0021		
Iron	0.13		
Organic Pollutant	**K_{oc}**	**f_{oc}**	**1/Partition Coefficient**
Naphthalene	1,995	0.63%	0.0796
Fluorene	3,900	0.63%	0.0407
Phenanthrene	14,000	0.63%	0.0113
Phenol	14	0.63%	11.34

Source: Offshore Environmental Assessment (Avanti Corporation, 1993).

Exhibit 4-13. Pore Water Pollutant Concentrations - Gulf of Mexico Deep Water Development Model Well, Current Technology

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Federal Criteria Exceedance Factor (d)
Naphthalene	0.0529	0.0795	4.59e-03		
Fluorene	0.0289	0.0407	1.28e-03	1.40e+01	
Phenanthrene	0.0684	0.0113	8.45e-04		
Phenol	3.80e-06	11.338	4.71e-05	4.60e+03	
Cadmium	0.0077	0.1100	9.28e-04	9.30e-03	
Mercury	0.0007	0.0180	1.38e-05	2.50e-05	
Antimony	0.0400			4.30e+00	
Arsenic	0.0498	0.0050	2.72e-04	1.40e-04	1.9
Beryllium	0.0049				
Chromium	1.6844	0.0340	6.26e-02	5.00e-02	1.3
Copper	0.1312	0.0063	9.03e-04	2.40e-03	
Lead	0.2463	0.0200	5.38e-03	8.10e-03	
Nickel	0.0947	0.0430	4.45e-03	8.20e-03	
Selenium	0.0077			7.10e-02	
Silver	0.0049			1.90e-03	
Thallium	0.0084			6.30e-03	
Zinc	1.4072	0.0041	6.30e-03	8.10e-02	
Aluminum	63.6558				
Barium	842.203	0.0021	1.93e+00		
Iron	107.6918	0.1300	1.53e+01		
Tin	0.1025				
Titanium	0.6141				
Alkylated benzenes	0.2978				
Alkylated naphthalenes	2.7998				
Alkylated fluorenes	0.3370				
Alkylated phenanthrenes	0.4258				
Alkylated phenols	0.0000				
Total biphenyls	0.5534				
Total dibenzothiophenes	0.0005				

(a) Pollutant concentration in sediment calculation shown in Appendix D.

(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water

(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.

(d) Pore water pollutant concentration exceeds the water quality criteria for arsenic (human health) by a factor of 1.9 and chromium (marine chronic) by a factor of 1.3.

Exhibit 4-14. Pore Water Pollutant Concentrations - Gulf of Mexico Deep Water Exploratory Model Well, Current Technology

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Federal Criteria Exceedance Factor (d)
Naphthalene	0.1177	0.0795	1.02e-02		
Fluorene	0.0642	0.0407	2.85e-03	1.40e+01	
Phenanthrene	0.1523	0.0113	1.88e-03		
Phenol	8.46e-06	11.338	1.05e-04	4.60e+03	
Cadmium	0.0172	0.1100	2.06e-03	9.30e-03	
Mercury	0.0016	0.0180	3.07e-05	2.50e-05	1.2
Antimony	0.0890			4.30e+00	
Arsenic	0.1108	0.0050	6.05e-04	1.40e-04	4.3
Beryllium	0.0109				
Chromium	3.7453	0.0340	1.39e-01	5.00e-02	2.8
Copper	0.2918	0.0063	2.01e-03	2.40e-03	
Lead	0.5478	0.0200	1.20e-02	8.10e-03	1.5
Nickel	0.2107	0.0430	9.90e-03	8.20e-03	1.2
Selenium	0.0172			7.10e-02	
Silver	0.0109			1.90e-03	
Thallium	0.0187			6.30e-03	
Zinc	3.1289	0.0041	1.40e-02	8.10e-02	
Aluminum	141.5403				
Barium	1,872.659	0.0021	4.30e+00		
Iron	239.4554	0.1300	3.40e+01		
Tin	0.2278				
Titanium	1.3655				
Alkylated benzenes	0.6625				
Alkylated naphthalenes	6.2284				
Alkylated fluorenes	0.7497				
Alkylated phenanthrenes	0.9473				
Alkylated phenols	0.0001				
Total biphenyls	1.2312				
Total dibenzothiophenes	0.0011				

(a) Pollutant concentration in sediment calculation shown in Appendix D.

(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water

(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.

(d) Pore water pollutant concentration exceeds the water quality criteria for mercury (marine chronic) by a factor of 1.2, arsenic (human health) by a factor of 4.3, chromium (marine chronic) by a factor of 2.8, lead (marine chronic) by a factor of 1.5, and nickel (marine chronic) by a factor of 1.2.

Exhibit 4-15. Pore Water Pollutant Concentrations - Gulf of Mexico Shallow Water Development Model Well, Current Technology

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Federal Criteria Exceedance Factor (d)
Naphthalene	0.0350	0.0795	3.04e-03		
Fluorene	0.0191	0.0407	8.49e-04	1.40e+01	
Phenanthrene	0.0453	0.0113	5.59e-04		
Phenol	2.52e-06	11.338	3.12e-05	4.60e+03	
Cadmium	0.0051	0.1100	6.13e-04	9.30e-03	
Mercury	0.0005	0.0180	9.12e-06	2.50e-05	
Antimony	0.0264			4.30e+00	
Arsenic	0.0329	0.0050	1.80e-04	1.40e-04	1.3
Beryllium	0.0032				
Chromium	1.1131	0.0340	4.13e-02	5.00e-02	
Copper	0.0867	0.0063	5.97e-04	2.40e-03	
Lead	0.1628	0.0200	3.56e-03	8.10e-03	
Nickel	0.0626	0.0430	2.94e-03	8.20e-03	
Selenium	0.0051			7.10e-02	
Silver	0.0032			1.90e-03	
Thallium	0.0056			6.30e-03	
Zinc	0.9299	0.0041	4.16e-03	8.10e-02	
Aluminum	42.0670				
Barium	556.571	0.0021	1.28e+00		
Iron	71.1682	0.1300	1.01e+01		
Tin	0.0677				
Titanium	0.4058				
Alkylated benzenes	0.1970				
Alkylated naphthalenes	1.8523				
Alkylated fluorenes	0.2230				
Alkylated phenanthrenes	0.2817				
Alkylated phenols	0.0000				
Total biphenyls	0.3662				
Total dibenzothiophenes	0.0003				

(a) Pollutant concentration in sediment calculation shown in Appendix D.

(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water

(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.

(d) Pore water pollutant concentration exceeds the water quality criterion for arsenic (human health) by a factor of 1.3.

Exhibit 4-16. Pore Water Pollutant Concentrations - Gulf of Mexico Shallow Water Exploratory Model Well, Current Technology

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Federal Criteria Exceedance Factor (d)
Naphthalene	0.0732	0.0795	6.36e-03		
Fluorene	0.0399	0.0407	1.78e-03	1.40e+01	
Phenanthrene	0.0947	0.0113	1.17e-03		
Phenol	5.26e-06	11.338	6.52e-05	4.60e+03	
Cadmium	0.0107	0.1100	1.28e-03	9.30e-03	
Mercury	0.0010	0.0180	1.91e-05	2.50e-05	
Antimony	0.0554			4.30e+00	
Arsenic	0.0690	0.0050	3.77e-04	1.40e-04	2.7
Beryllium	0.0068				
Chromium	2.3326	0.0340	8.66e-02	5.00e-02	1.7
Copper	0.1818	0.0063	1.25e-03	2.40e-03	
Lead	0.3411	0.0200	7.45e-03	8.10e-03	
Nickel	0.1312	0.0430	6.16e-03	8.20e-03	
Selenium	0.0107			7.10e-02	
Silver	0.0068			1.90e-03	
Thallium	0.0117			6.30e-03	
Zinc	1.9487	0.0041	8.73e-03	8.10e-02	
Aluminum	88.1537				
Barium	1,166.324	0.0021	2.68e+00		
Iron	149.1369	0.1300	2.12e+01		
Tin	0.1419				
Titanium	0.8504				
Alkylated benzenes	0.4123				
Alkylated naphthalenes	3.8760				
Alkylated fluorenes	0.4666				
Alkylated phenanthrenes	0.5895				
Alkylated phenols	0.0000				
Total biphenyls	0.7662				
Total dibenzothiophenes	0.0007				

(a) Pollutant concentration in sediment calculation shown in Appendix D.

(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water

(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.

(d) Pore water pollutant concentration exceeds water quality criteria for arsenic (human health) by a factor of 2.7 and chromium (marine chronic) by a factor of 1.7.

Exhibit 4-17. Pore Water Pollutant Concentrations - Gulf of Mexico Deep Water Development Model Well, Discharge Option

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Federal Criteria Exceedance Factor (d)
Naphthalene	0.0303	0.0795	2.63e-03		
Fluorene	0.0165	0.0407	7.35e-04	1.40e+01	
Phenanthrene	0.0392	0.0113	4.84e-04		
Phenol	2.18e-06	11.338	2.70e-05	4.60e+03	
Cadmium	0.0044	0.1100	5.31e-04	9.30e-03	
Mercury	0.0004	0.0180	7.90e-06	2.50e-05	
Antimony	0.0229			4.30e+00	
Arsenic	0.0285	0.0050	1.56e-04	1.40e-04	1.1
Beryllium	0.0028				
Chromium	0.9641	0.0340	3.58e-02	5.00e-02	
Copper	0.0751	0.0063	5.17e-04	2.40e-03	
Lead	0.1410	0.0200	3.08e-03	8.10e-03	
Nickel	0.0542	0.0430	2.55e-03	8.20e-03	
Selenium	0.0044			7.10e-02	
Silver	0.0028			1.90e-03	
Thallium	0.0048			6.30e-03	
Zinc	0.8054	0.0041	3.61e-03	8.10e-02	
Aluminum	36.4354				
Barium	482.062	0.0021	1.11e+00		
Iron	61.6409	0.1300	8.75e+00		
Tin	0.0587				
Titanium	0.3515				
Alkylated benzenes	0.1707				
Alkylated naphthalenes	1.6045				
Alkylated fluorenes	0.1931				
Alkylated phenanthrenes	0.2440				
Alkylated phenols	0.0000				
Total biphenyls	0.3172				
Total dibenzothiophenes	0.0003				

(a) Pollutant concentration in sediment calculation shown in Appendix D.

(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water

(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.

(d) Pore water pollutant concentrations exceed the water quality criterion for arsenic (human health) by a factor of 1.1.

Exhibit 4-18. Pore Water Pollutant Concentrations - Gulf of Mexico Deep Water Exploratory Model Well, Discharge Option

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Federal Criteria Exceedance Factor (d)
Naphthalene	0.0674	0.0795	5.85e-03		
Fluorene	0.0368	0.0407	1.63e-03	1.40e+01	
Phenanthrene	0.0872	0.0113	1.08e-03		
Phenol	4.84e-06	11.338	6.00e-05	4.60e+03	
Cadmium	0.0098	0.1100	1.18e-03	9.30e-03	
Mercury	0.0009	0.0180	1.76e-05	2.50e-05	
Antimony	0.0509			4.30e+00	
Arsenic	0.0634	0.0050	3.46e-04	1.40e-04	2.5
Beryllium	0.0063				
Chromium	2.1437	0.0340	7.96e-02	5.00e-02	1.6
Copper	0.1670	0.0063	1.15e-03	2.40e-03	
Lead	0.3135	0.0200	6.85e-03	8.10e-03	
Nickel	0.1206	0.0430	5.66e-03	8.20e-03	
Selenium	0.0098			7.10e-02	
Silver	0.0063			1.90e-03	
Thallium	0.0107			6.30e-03	
Zinc	1.7909	0.0041	8.02e-03	8.10e-02	
Aluminum	81.0149				
Barium	1,071.874	0.0021	2.46e+00		
Iron	137.0596	0.1300	1.95e+01		
Tin	0.1304				
Titanium	0.7816				
Alkylated benzenes	0.3793				
Alkylated naphthalenes	3.5663				
Alkylated fluorenes	0.4293				
Alkylated phenanthrenes	0.5424				
Alkylated phenols	0.0000				
Total biphenyls	0.7050				
Total dibenzothiophenes	0.0006				

(a) Pollutant concentration in sediment calculation shown in Appendix D.
(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water
(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.
(d) Pore water pollutant concentrations exceed the water quality criteria for arsenic (human health) by a factor of 2.5 and chromium (marine chronic) by a factor of 1.6.

Exhibit 4-19. Pore Water Pollutant Concentrations - Gulf of Mexico Shallow Water Development Model Well, Discharge Option

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Federal Criteria Exceedance Factor (d)
Naphthalene	0.0201	0.0795	1.74e-03		
Fluorene	0.0109	0.0407	4.87e-04	1.40e+01	
Phenanthrene	0.0260	0.0113	3.20e-04		
Phenol	1.44e-06	11.338	1.79e-05	4.60e+03	
Cadmium	0.0029	0.1100	3.51e-04	9.30e-03	
Mercury	0.0003	0.0180	5.22e-06	2.50e-05	
Antimony	0.0151			4.30e+00	
Arsenic	0.0188	0.0050	1.03e-04	1.40e-04	
Beryllium	0.0019				
Chromium	0.6371	0.0340	2.37e-02	5.00e-02	
Copper	0.0496	0.0063	3.42e-04	2.40e-03	
Lead	0.0932	0.0200	2.04e-03	8.10e-03	
Nickel	0.0358	0.0430	1.68e-03	8.20e-03	
Selenium	0.0029			7.10e-02	
Silver	0.0019			1.90e-03	
Thallium	0.0032			6.30e-03	
Zinc	0.5323	0.0041	2.38e-03	8.10e-02	
Aluminum	24.0779				
Barium	318.565	0.0021	7.31e-01		
Iron	40.7346	0.1300	5.78e+00		
Tin	0.0388				
Titanium	0.2323				
Alkylated benzenes	0.1129				
Alkylated naphthalenes	1.0618				
Alkylated fluorenes	0.1278				
Alkylated phenanthrenes	0.1615				
Alkylated phenols	0.0000				
Total biphenyls	0.2099				
Total dibenzothiophenes	0.0002				

(a) Pollutant concentration in sediment calculation shown in Appendix D.
(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water
(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.
(d) No Federal water quality criteria are exceeded.

Exhibit 4-20. Pore Water Pollutant Concentrations - Gulf of Mexico Shallow Water Exploratory Model Well, Discharge Option

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Federal Criteria Exceedance Factor (d)
Naphthalene	0.0419	0.0795	3.64e-03		
Fluorene	0.0229	0.0407	1.02e-03	1.40e+01	
Phenanthrene	0.0542	0.0113	6.69e-04		
Phenol	3.01e-06	11.338	3.73e-05	4.60e+03	
Cadmium	0.0061	0.1100	7.35e-04	9.30e-03	
Mercury	0.0006	0.0180	1.09e-05	2.50e-05	
Antimony	0.0317			4.30e+00	
Arsenic	0.0395	0.0050	2.16e-04	1.40e-04	
Beryllium	0.0039				
Chromium	1.3352	0.0340	4.96e-02	5.00e-02	
Copper	0.1040	0.0063	7.16e-04	2.40e-03	
Lead	0.1953	0.0200	4.27e-03	8.10e-03	
Nickel	0.0751	0.0430	3.53e-03	8.20e-03	
Selenium	0.0061			7.10e-02	
Silver	0.0039			1.90e-03	
Thallium	0.0067			6.30e-03	
Zinc	1.1154	0.0041	5.00e-03	8.10e-02	
Aluminum	50.4577				
Barium	667.584	0.0021	1.53e+00		
Iron	85.3634	0.1300	1.21e+01		
Tin	0.0812				
Titanium	0.4868				
Alkylated benzenes	0.2360				
Alkylated naphthalenes	2.2188				
Alkylated fluorenes	0.2671				
Alkylated phenanthrenes	0.3374				
Alkylated phenols	0.0000				
Total biphenyls	0.4386				
Total dibenzothiophenes	0.0004				

(a) Pollutant concentration in sediment calculation shown in Appendix D.
(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water
(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.
(d) No Federal water quality criteria are exceeded.

The resulting average base fluid concentration at 100 m (8,655 mg/kg) is used to calculate the pore water concentrations of individual pollutants in synthetic fluids for a shallow water exploratory model well. As for the Gulf of Mexico analysis, the concentration of base fluid at 100 meters is multiplied by the proportion of total oil discharged relative to a shallow exploratory well to calculate the other model well type pollutant concentrations. These resulting concentration at 100 meters for each pollutant is multiplied by the pollutant-specific leach factor for metals or divided by the partition coefficient for organic pollutants to derive pore water pollutant concentrations.

EPA projects that only development wells will be drilled in both Cook Inlet, Alaska (shallow only) and offshore California (both shallow and deep). EPA does not project the drilling of any exploratory wells in these areas, and for this reason model results concerning exploratory wells are not shown. Although operators in Cook Inlet, Alaska and offshore California currently cannot discharge SBF-cuttings, EPA presents pore water pollutant concentrations for these areas based on the current treatment technology (11% retention on cuttings) for the purpose of comparison with the discharge option results. The pore water pollutant concentrations for the current technology and discharge option are compared to Federal water quality criteria and Alaska state standards in Exhibits 4-21 through 4-24.

Exhibit 4-21. Pore Water Pollutant Concentrations - California Deep Water Development Model Well, Current Technology

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l)	Federal Water Quality Criteria (mg/l) (b)	Federal Criteria Exceedance Factor (c)
Naphthalene	0.0330	0.0795	2.86e-03		
Fluorene	0.0180	0.0407	7.99e-04	1.40e+01	
Phenanthrene	0.0426	0.0113	5.26e-04		
Phenol	2.37e-06	11.338	2.93e-05	4.60e+03	
Cadmium	0.0048	0.1100	5.78e-04	9.30e-03	
Mercury	0.0004	0.0180	8.60e-06	2.50e-05	
Antimony	0.0249			4.30e+00	
Arsenic	0.0310	0.0050	1.70e-04	1.40e-04	1.2
Beryllium	0.0031				
Chromium	1.0494	0.0340	3.90e-02	5.00e-02	
Copper	0.0818	0.0063	5.63e-04	2.40e-03	
Lead	0.1535	0.0200	3.35e-03	8.10e-03	
Nickel	0.0590	0.0430	2.77e-03	8.20e-03	
Selenium	0.0048			7.10e-02	
Silver	0.0031			1.90e-03	
Thallium	0.0052			6.30e-03	
Zinc	0.8767	0.0041	3.93e-03	8.10e-02	
Aluminum	39.6583				
Barium	524.702	0.0021	1.20e+00		
Iron	67.0932	0.1300	9.53e+00		
Tin	0.0638				
Titanium	0.3826				
Alkylated benzenes	0.1855				
Alkylated naphthalenes	1.7443				
Alkylated fluorenes	0.2100				
Alkylated phenanthrenes	0.2653				
Alkylated phenols	0.0000				
Total biphenyls	0.3448				
Total dibenzothiophenes	0.0003				

(a) Pollutant concentration in sediment calculation shown in Appendix D.

(b) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.

(c) Pore water pollutant concentration exceeds the water quality criterion for arsenic (human health) by a factor of 1.2.

Exhibit 4-22. Pore Water Pollutant Concentrations - Cook Inlet, Alaska and Offshore California Shallow Water Development Model Well, Current Technology

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Alaska State Standards (mg/l)	Criteria/ Standards Exceedance Factor (d)
Naphthalene	0.0218	0.0795	1.89e-03			
Fluorene	0.0119	0.0407	5.29e-04	1.40e+01		
Phenanthrene	0.0282	0.0113	3.48e-04			
Phenol	1.57e-06	11.338	1.94e-05	4.60e+03		
Cadmium	0.0032	0.1100	3.82e-04	9.30e-03		
Mercury	0.0003	0.0180	5.68e-06	2.50e-05		
Antimony	0.0165			4.30e+00	6.00e-03	
Arsenic	0.0205	0.0050	1.12e-04	1.40e-04	5.00e-01	
Beryllium	0.0020				4.00e-03	
Chromium	0.6935	0.0340	2.58e-02	5.00e-02	1.00e-01	
Copper	0.0540	0.0063	3.72e-04	2.40e-03		
Lead	0.1014	0.0200	2.22e-03	8.10e-03		
Nickel	0.0390	0.0430	1.82e-03	8.20e-03	1.00e-01	
Selenium	0.0032			7.10e-02	5.00e-02	
Silver	0.0020			1.90e-03		
Thallium	0.0035			6.30e-03	2.00e-03	
Zinc	0.5794	0.0041	2.60e-03	8.10e-02		
Aluminum	26.2082					
Barium	346.750	0.0021	7.95e-01		2.00e+00	
Iron	44.3386	0.1300	6.30e+00			
Tin	0.0422					
Titanium	0.2528					
Alkylated benzenes	0.1227					
Alkylated naphthalenes	1.1540					
Alkylated fluorenes	0.1389					
Alkylated phenanthrenes	0.1755					
Alkylated phenols	0.0000					
Total biphenyls	0.2281					
Total dibenzothiophenes	0.0002					

(a) Pollutant concentration in sediment calculation shown in Appendix D.

(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water

(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.

(d) No Federal water quality criteria or state standards are exceeded.

Exhibit 4-23. Pore Water Pollutant Concentrations - California Deep Water Development Model Well, Discharge Option

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Federal Criteria Exceedance Factor (d)
Naphthalene	0.0189	0.0795	1.64e-03		
Fluorene	0.0103	0.0407	4.58e-04	1.40e+01	
Phenanthrene	0.0244	0.0113	3.02e-04		
Phenol	1.36e-06	11.338	1.68e-05	4.60e+03	
Cadmium	0.0028	0.1100	3.31e-04	9.30e-03	
Mercury	0.0003	0.0180	4.92e-06	2.50e-05	
Antimony	0.0143			4.30e+00	
Arsenic	0.0178	0.0050	9.70e-05	1.40e-04	
Beryllium	0.0018				
Chromium	0.6007	0.0340	2.23e-02	5.00e-02	
Copper	0.0468	0.0063	3.22e-04	2.40e-03	
Lead	0.0878	0.0200	1.92e-03	8.10e-03	
Nickel	0.0338	0.0430	1.59e-03	8.20e-03	
Selenium	0.0028			7.10e-02	
Silver	0.0018			1.90e-03	
Thallium	0.0030			6.30e-03	
Zinc	0.5018	0.0041	2.25e-03	8.10e-02	
Aluminum	22.700				
Barium	300.33	0.0021	6.89e-01		
Iron	38.403	0.1300	5.45e+00		
Tin	0.0365				
Titanium	0.2190				
Alkylated benzenes	0.1063				
Alkylated naphthalenes	0.9996				
Alkylated fluorenes	0.1203				
Alkylated phenanthrenes	0.1520				
Alkylated phenols	0.0000				
Total biphenyls	0.1976				
Total dibenzothiophenes	0.0002				

(a) Pollutant concentration in sediment calculation shown in Appendix D.

(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water

(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.

(d) No Federal water quality criteria are exceeded.

Exhibit 4-24. Pore Water Pollutant Concentrations - Cook Inlet, Alaska and Offshore California Shallow Water Development Model Well, Discharge Option

Pollutant	Poll. Conc. in Sediment at 100 m (mg/kg) (a)	Partition Coefficient^-1 or Leach Factor	Pore Water Conc. (mg/l) (b)	Federal Water Quality Criteria (mg/l) (c)	Alaska State Standards (mg/l)	Criteria/ Standards Exceedance Factor (d)
Naphthalene	0.0125	0.0795	1.09e-03			
Fluorene	0.0068	0.0407	3.03e-04	1.40e+01		
Phenanthrene	0.0162	0.0113	2.00e-04			
Phenol	8.98e-07	11.338	1.11e-05	4.60e+03		
Cadmium	0.0018	0.1100	2.19e-04	9.30e-03		
Mercury	0.0002	0.0180	3.25e-06	2.50e-05		
Antimony	0.0094			4.30e+00	6.00e-03	
Arsenic	0.0117	0.0050	6.41e-05	1.40e-04	5.00e-01	
Beryllium	0.0012				4.00e-03	
Chromium	0.3969	0.0340	1.47e-02	5.00e-02	1.00e-01	
Copper	0.0309	0.0063	2.13e-04	2.40e-03		
Lead	0.0581	0.0200	1.27e-03	8.10e-03		
Nickel	0.0223	0.0430	1.05e-03	8.20e-03	1.00e-01	
Selenium	0.0018			7.10e-02	5.00e-02	
Silver	0.0012			1.90e-03		
Thallium	0.0020			6.30e-03	2.00e-03	
Zinc	0.3316	0.0041	1.49e-03	8.10e-02		
Aluminum	15.0008					
Barium	198.470	0.0021	4.55e-01		2.00e+00	
Iron	25.3781	0.1300	3.60e+00			
Tin	0.0241					
Titanium	0.1447					
Alkylated benzenes	0.0704					
Alkylated naphthalenes	0.6615					
Alkylated fluorenes	0.0796					
Alkylated phenanthrenes	0.1006					
Alkylated phenols	0.0000					
Total biphenyls	0.1308					
Total dibenzothiophenes	0.0001					

(a) Pollutant concentration in sediment calculation shown in Appendix D.
(b) Pore water conc. = Poll. Conc. in Sediment * Partition Coeff^{-1} or Leach Factor * 35.5 kg sediment/32.5 l pore water
(c) Most stringent criterion shown on this table representing marine acute, marine chronic, and human health (fish consumption) criteria (see Exhibit 4-1); there are no Federal water quality criteria for specific SBF compounds.
(d) No Federal water quality criteria or state standards are exceeded.

4.4 Sediment Guidelines for the Protection of Benthic Organisms

An additional method for assessing potential benthic impacts of certain metals is EPA's proposed sediment guidelines for the protection of benthic organisms (EPA, 1998b). These proposed guidelines are based on an equilibrium partitioning (EqP) approach to determine guidelines based on "numerical concentrations for individual chemicals that are applicable across the range of sediments encountered in practice." The EqP sediment guidelines (ESG) for the six metals copper, cadmium, nickel, lead, silver, and zinc account for the additive toxicity effects of these metals. They are derived by two procedures: (a) by comparing the sum of the metal's molar concentrations, measured as simultaneously extracted metal (SEM), to the molar concentration of acid volatile sulfide (AVS) in sediments:

$$\sum_i [SEM] \leq [AVS]$$

or (b) by comparing the measured interstitial water [i.e., pore water] concentrations of the metals to water quality criteria final chronic values (FCVs):

$$\sum_i [M_{i,\,d}]/[FCV_{i,\,d}] \leq 1$$

for the i^{th} metal with a total dissolved concentration ($M_{i,\,d}$). Meeting one or both of these conditions indicates that benthic organisms should be acceptably protected.

For this environmental analysis, the second (interstitial water guideline) method is used to assess potential impacts. The pore water concentrations presented in section 4.3 are used for the following analyses. The sum of the interstitial water concentration:FCV ratios for the six metals is calculated for each of the model wells. Exhibits 4-25 and 4-26 present the ESG analysis for Gulf of Mexico wells for current technology and the discharge option, respectively. Exhibit 4-27 presents the analysis for Cook Inlet, Alaska and offshore California model wells.

All model wells in the Gulf of Mexico fail to meet the sediment guidelines using the current technology, with concentration:FCV ratios ranging from 1.2 to 3.9. Under the discharge option, the development model wells meet the guideline. The exploratory model wells do not meet the guideline, but the projected pollutant pore water concentrations are 43 percent lower compared to those projected for the current industry practice. For Cook Inlet, Alaska and offshore California, the deep and shallow development model wells pass the guidelines using both the current technology and the discharge option technology.

Exhibit 4-25. Sediment Guidelines Analysis - Gulf of Mexico, Current Technology

Metal	Pore Water Conc. At 100 m (μg/l) (a)	FCV (μg/l) (b)	Conc./FCV (c)
Deep Water Development Model Well			
Cadmium	0.928	9.3	0.0998
Copper	0.903	2.4	0.376
Lead	5.38	8.1	0.664
Nickel	4.45	8.2	0.543
Silver	-	-	-
Zinc	6.30	81	0.0778
		Sum =	1.8
Deep Water Exploration Model Well			
Cadmium	2.06	9.3	0.221
Copper	2.01	2.4	0.837
Lead	11.97	8.1	1.48
Nickel	9.89	8.2	1.21
Silver	-	-	-
Zinc	14.0	81	0.170
		Sum =	3.9
Shallow Water Development Model Well			
Cadmium	0.613	9.3	0.0659
Copper	0.597	2.4	0.249
Lead	3.56	8.1	0.439
Nickel	2.94	8.2	0.358
Silver	-	-	-
Zinc	4.16	81	0.0513
		Sum =	1.7
Shallow Water Exploratory Model Well			
Cadmium	1.28	9.3	0.138
Copper	1.25	2.4	0.521
Lead	7.45	8.1	0.920
Nickel	6.16	8.2	0.752
Silver	-	-	-
Zinc	8.73	81	0.108
		Sum =	2.4

(a) Pore water concentration calculated in Exhibits 4-13 through 4-16.
(b) FCV = final chronic value = marine chronic water quality criterion.
(c) The guideline is met if the sum of Conc./FCV is ≤ 1. All Gulf of Mexico model wells exceed the sediment guidelines using the current practice. See Appendix A for revised FCVs and analysis of changes to this assessment due to the revisions. See footnote 1, page 4-2.

Exhibit 4-26. Sediment Guidelines Analysis - Gulf of Mexico, Discharge Option

Metal	Pore Water Conc. At 100 m (µg/l) (a)	FCV (µg/l) (b)	Conc./FCV (c)
Deep Water Development Model Well			
Cadmium	0.531	9.3	0.0571
Copper	0.517	2.4	0.215
Lead	3.08	8.1	0.380
Nickel	2.55	8.2	0.311
Silver	-	-	-
Zinc	3.61	81	0.0446
		Sum =	1.0
Deep Water Exploratory Model Well			
Cadmium	1.18	9.3	0.127
Copper	1.15	2.4	0.479
Lead	6.85	8.1	0.846
Nickel	5.66	8.2	0.690
Silver	-	-	-
Zinc	8.02	81	0.0990
		Sum =	2.2
Shallow Water Development Model Well			
Cadmium	0.351	9.3	0.0377
Copper	0.342	2.4	0.143
Lead	2.04	8.1	0.252
Nickel	1.68	8.2	0.205
Silver	-	-	-
Zinc	2.38	81	0.0294
		Sum =	0.67
Shallow Water Exploratory Model Well			
Cadmium	0.735	9.3	0.0790
Copper	0.716	2.4	0.298
Lead	4.27	8.1	0.527
Nickel	3.53	8.2	0.430
Silver	-	-	-
Zinc	4.99	81	0.0616
		Sum =	1.4

(a) Pore water concentration calculated in Exhibits 4-17 through 4-20.

(b) FCV = final chronic value = marine chronic water quality criterion.

(c) The guideline is met if the sum of Conc./FCV is ≤ 1. The Gulf of Mexico exploratory model wells exceed the sediment guidelines under the discharge option. See Appendix A for revised FCVs and analysis of changes to this assessment due to the revisions. See footnote 1, page 4-2.

Exhibit 4-27. Sediment Guidelines Analysis - Cook Inlet, Alaska and Offshore California

Metal	Pore Water Conc. At 100 m (µg/l) (a)	FCV (µg/l) (b)	Conc./FCV
Deep Water Development Model Well, Current Technology			
Cadmium	0.578	9.3	0.0622
Copper	0.563	2.4	0.234
Lead	3.35	8.1	0.413
Nickel	2.77	8.2	0.338
Silver	-	-	-
Zinc	3.93	81	0.0485
		Sum =	1.1
Deep Water Development Model Well, Discharge Option			
Cadmium	0.331	9.3	0.0356
Copper	0.322	2.4	0.134
Lead	1.92	8.1	0.237
Nickel	1.59	8.2	0.194
Silver	-	-	-
Zinc	2.25	81	0.0278
		Sum =	0.63
Shallow Water Development Model Well, Current Technology			
Cadmium	0.382	9.3	0.0411
Copper	0.372	2.4	0.155
Lead	2.22	8.1	0.274
Nickel	1.83	8.2	0.223
Silver	-	-	-
Zinc	2.59	81	0.32
		Sum =	0.73
Shallow Water Development Model Well, Discharge Option			
Cadmium	0.219	9.3	0.0235
Copper	0.213	2.4	0.0887
Lead	1.27	8.1	0.157
Nickel	1.05	8.2	0.128
Silver	-	-	-
Zinc	1.48	81	0.0183
		Sum =	0.42

(a) Pore water concentration calculated in Exhibits 4-21 through and 4-24.
(b) FCV = final chronic value = marine chronic water quality criterion.
(c) The guideline is met if the sum of Conc./FCV is $\leq$ 1. The Cook Inlet, Alaska and offshore California development model wells meet the sediment guidelines under the discharge option. See Appendix A for revised FCVs and analysis of changes to this assessment due to the revisions. See footnote 1, page 4-2.

5. HUMAN HEALTH RISKS

5.1 Introduction

This portion of the environmental analysis presents the human health-related risks and risk reductions (benefits) of current technology and the discharge and zero discharge regulatory options. EPA based the health risks and benefits analysis on human exposure to carcinogenic and noncarcinogenic contaminants through consumption of affected seafood; specifically, recreationally-caught finfish and commercially-caught shrimp. EPA used seafood consumption and lifetime exposure duration assumptions to estimate risks and benefits under each of the discharge scenarios for the three geographic regions where the discharge of SBF-cuttings will be affected by this rule. The analysis is performed for those contaminants for which bioconcentration factors, oral reference doses (RfDs), or oral slope factors for carcinogenic risks have been established. Thus, the analysis considers contaminants associated with the drilling fluid barite and with contamination by formation (crude) oil, but does not consider the synthetic base compounds themselves.

5.2 Recreational Fisheries Tissue Concentrations

Exposure of recreational finfish to drilling fluid contaminants occurs through the uptake of dissolved pollutants found in the water column. Instead of using the water column pollutant concentrations at the edge of the mixing zone (as for the water quality analyses), EPA calculates an average water column concentration of each pollutant for the area *within* a 100-m radius of the discharge. As described in Chapter 4, Brandsma's 1996 study was used to determine base fluid concentrations at specified distances from a discharge point. Also as presented in Chapter 4, Brandsma does not provide concentrations as a function of distance, but rather as a function of time. Therefore, to calculate an average concentration within 100 m, the time required for transport to the edge of the mixing zone was calculated as the quotient of the distance to the edge of the mixing zone and the current speed (100 meters/current speed, in m/sec). Based on this transport time, equal time intervals (and therefore radial distances) were chosen to create a series of base fluid concentrations at varying radii across the total radius of the mixing zone. These concentrations were used to calculate the dilutions achieved at these distances using the method described in Chapter 4 (section 4.2). The average dilution for the area within 100 meters was derived from these estimated dilutions between the discharge point and the 100-meter boundary. The base fluid concentrations from Brandsma (1996), the calculated dilutions, and the average dilutions used are presented below in the discussions for each geographic region.

The average dilution available within 100 m is used to determine the ambient bioavailable concentrations of pollutants associated with the SBF within the effluent plume by multiplying the average number of dilutions by the respective initial pollutant concentrations. For metals, these pollutant concentrations are further adjusted by leach factors to account for the amount of the metal dissolved, and therefore, bioavailable. These dissolved metals remain in the part of the plume that is diluted in the water column instead of settling to the seafloor with the larger solids. This resulting exposure concentration of SBF pollutants characterizes only the area within the discharge plume. Within the mixing zone, however, the water column also contains "uncontaminated" waters. Thus, for the exposure of finfish within the 100-m mixing zone, the effective exposure concentration is the exposure concentration adjusted by the volumetric proportion of the total water column that contains the discharge plume. This volumetric proportion represents the proportion of time that exposure would occur assuming the fish have an equal probability of being present (and therefore exposed) anywhere in the entire cylinder that makes up the mixing zone. This proportion is determined in the following manner:

exposure proportion = discharge plume volume/water column volume
= discharge rate (m^3/min) * t_T (time to reach 100 m; min)/$\pi r^2 h$

where:

discharge rate = 25.1 m^3/day (= 0.0175 m^3/min)
t_T = 100 m/current speed (m/sec)
r = 100 m
h = depth affected by the plume, which = fall velocity * t_T; where fall velocity = 0.015 m/sec (Delvigne, 1996).

The effective exposure concentration of each pollutant is multiplied by this exposure proportion and by a pollutant-specific bioconcentration factor (BCF) to yield the tissue concentration of each pollutant in finfish on a mg/kg basis. Pollutant-specific BCFs used for this analysis are presented in Exhibit 5-1. These calculated tissue concentrations represent a potential upper estimate of contamination for fish contained within a 100-m radius of a discharge of SBF-cuttings. The following sections provide the geographic region-specific input parameters for the tissue concentration calculations. The calculations and resulting finfish tissue pollutant concentrations are presented in Appendix E.

5.2.1 *Gulf of Mexico*

The transport time for discharges in the Gulf of Mexico is based on a 15 cm/sec current speed (MMS, 1989), resulting in an 11 minute estimation for the plume to reach 100 meters. The time intervals used for the average dilutions within the mixing zone and the extracted base fluid concentration data from Brandsma (1996) are presented in Exhibit 5-2. The tissue concentrations are presented in Appendix E, Exhibits E-1 and E-2 for the current technology and discharge option, respectively.

Exhibit 5-1. Pollutant-Specific Bioconcentration Factors

Pollutant	BCF (l/kg) (a)
Naphthalene	426
Fluorene	30
Phenanthrene	2,630
Phenol	1.4
Cadmium	64
Mercury	5,500
Antimony	1
Arsenic	44
Beryllium	19
Chromium	16
Copper	36
Lead	49
Nickel	47
Selenium	4.8
Silver	0.5
Thallium	116
Zinc	47
Aluminum	231

(a) There are no BCFs for specific SBF compounds.
Source: Offshore Environmental Assessment (Avanti, 1993)

Exhibit 5-2. Calculation of Average Dilutions within Gulf of Mexico Mixing Zone

Time (t; min.)	1	3	5	7	9	11	Avg.
Base fluid concentration @ t (mg/l)	73	32	20	10	9	3.2	
Initial base fluid content in cuttings (mg/l)	112,750						
Calculated Dilutions	1,545	3,523	5,638	11,275	12,528	35,234	11,624

Source: Derived from Figure 2, Brandsma (1996); see Appendix C.

5.2.2 *Cook Inlet, Alaska*

The transport time for discharges in Cook Inlet, Alaska is based on a 40 cm/sec current speed (EPA Region 10, 1984), resulting in a 4.2 minute estimation for the plume to reach 100 meters. The time intervals used to calculate the average dilutions within the mixing zone and the extracted OBF concentration data from Brandsma (1996) are presented in Exhibit 5-3.

Exhibit 5-3. Calculation of Average Dilutions within Cook Inlet, Alaska and Offshore California Mixing Zones

Time (t; min.)	1	2	3	4	5	Avg.
Base fluid concentration @ t (mg/l)	73	45.5	32	28	20	
Initial base fluid concentration in cuttings (mg/l)	112,750					
Calculated Dilutions	1,545	2,478	3,523	4,027	5,638	
Alaska (4.2 minutes)						2,893
California (5.5 minutes)						3,442

Source: Derived from Figure 2, Brandsma (1996); see Appendix B.

The calculations for determining the finfish tissue concentrations including the calculations of the proportion of the plume impacting Cook Inlet, Alaska mixing zones are presented in Appendix E, Exhibits E-3 and E-4 for the current technology and the discharge option, respectively. Although current practice in Cook Inlet, Alaska is zero discharge of SBF-cuttings, the analysis of current technology is presented for comparison with the discharge option.

5.2.3 *Offshore California*

The transport time for discharges offshore California is based on a 30 cm/sec current speed (MMS, 1985), resulting in a 5.5 minute estimation for the plume to reach 100 meters. The time intervals used to calculate the average dilutions within the mixing zone and the extracted base fluid concentration data from Brandsma (1996) are presented in Exhibit 5-3, above.

The calculations for determining the finfish tissue concentrations including the calculations of the proportion of the plume impacting offshore California mixing zones are presented in Appendix E, Exhibits E-5 and E-6 for current technology and the discharge option, respectively. Although current practice in offshore California is zero discharge of SBF-cuttings, the analysis of current technology is presented for the purpose of comparison with the discharge option.

5.3 Commercial Fisheries Shrimp Tissue Concentrations

EPA based projected shrimp tissue concentrations of pollutants from SBF discharges on the uptake of pollutants from sediment pore water. The pore water pollutant concentrations are based on the assumption of even distribution of the total annual SBF discharge over an area of impact surrounding the model well. The area of impact was determined using the 11-well synthetic fluid sediment concentration data described in section 4.3.1. For each distance from the well, the corresponding sediment concentrations of synthetic base fluids were averaged and plotted (see Exhibit 5-4).

Based on a log:log regression of these data, the distances to various concentrations of synthetic base fluids were determined (i.e., order of magnitude sediment concentrations ranging from 1 mg/kg to 100,000 mg/kg). A study by Berge (1996) observed the environmental effects (faunal changes) of treated OBF-cuttings on a natural seabed. Based upon the analyses provided in Berge (1996), a no effect threshold was set at 100 mg/kg. The radial distance to that sediment concentration (772 m as determined in Exhibit 5-4) results in an associated impact area of 1.9 km^2, which is used for the analyses presented in this section.

While Berge indicates the usage of a 1,000 mg/kg threshold can be determined from data in the study, the analyses are confounded by the statistical necessity of combining the data set into low and high synthetic base fluid content groupings for the analyses. The low synthetic base fluid content group was composed of cuttings treatments that resulted in residual base fluid levels of 150 mg/kg and 990 mg/kg. Thus, Berge also offers that the no effect concentration found in the experiments ranged from 150 ppm to 1,000 ppm of base fluid in sediment. For this analyses, therefore, a no effect threshold of 100 mg/kg is used.

In order to calculate the discharge pollutant distribution over the 1.9 km^2 impact area, the following assumptions that were applicable in the Environmental Assessment for the offshore effluent guidelines are used for this current SBF assessment (Avanti Corporation, 1993):

- Sediment depth affected = 5 cm
- Unit volume sediment affected = 0.05 m^3
- Density of sediment = 710 kg/m^3
- Mass of unit volume sediment = 35.5 kg
- Volume of water in unit volume of sediment = 32.5 liters

- Impact radius = 772 m; impact area = 1.9 km^2
- Sediment mass = (impact area * sed. depth * sediment density) = 1.9×10^6 m^2 * 0.05 m * 710 kg/m^3 = 6.745e+07 kg
- Average pollutant concentration (mg poll. / kg sed.) = poll. loadings / sed. mass
- Shrimp tissue concentration = (avg. poll. conc.) * (leach factor or partition $coeff.^{-1}$) * 35.5 kg sediment/32.5 l water * (BCF) * (% lipids).

The above assumptions are used to calculate the average pollutant concentrations in pore water at any point within the well impact area. The calculations of these sediment pollutant concentrations for Gulf of Mexico SBF-cuttings discharges are presented in Appendix F. To obtain the pollutant concentrations in shrimp tissue, the pore water concentration is multiplied by a pollutant-specific BCF, and is adjusted for a shrimp lipid content of 1.1% (Avanti Corporation, 1993). The bioconcentration factors used in the current analysis are listed in Exhibit 5-1. The following sections (5.3.1 through 5.3.3) present the input parameters for calculating the shrimp tissue pollutant concentration for each of the geographic areas (Gulf of Mexico, Cook Inlet, Alaska, and offshore California) using the current technology (11% retention on cuttings) or the discharge option (7% retention on cuttings). The shrimp tissue concentrations do not serve as endpoints for this analysis, but rather are used for estimating the health risks presented in section 5.5 of this chapter.

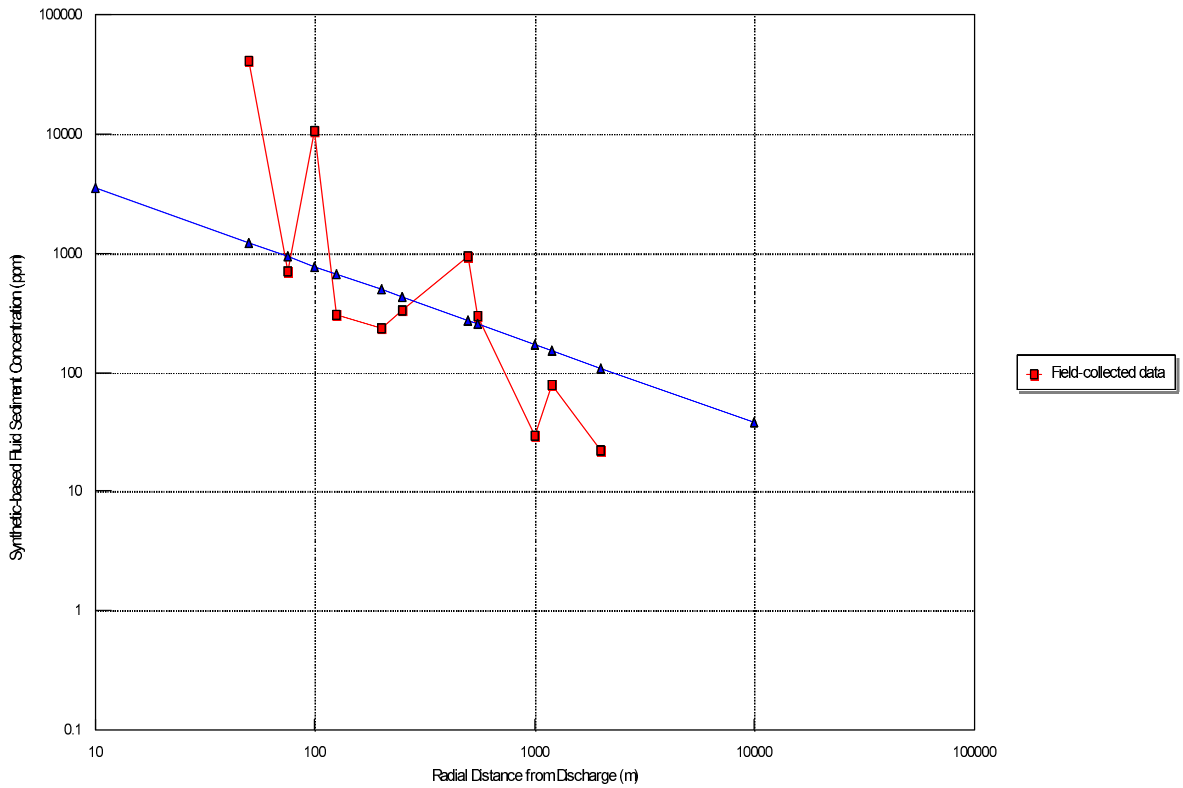
5.3.1 *Gulf of Mexico*

The concentrations of pollutants in shrimp tissue are presented in Appendix G, Exhibits G-1 through G-4 for Gulf of Mexico model wells using current technology and the discharge option. Only shallow water wells are considered for shrimp impact analysis because shrimp are harvested mainly from waters potentially affected by drilling discharges from shallow water development and exploratory model wells.

5.3.2 *Cook Inlet, Alaska*

Shrimp harvesting by trawling or pot fishing is prohibited in Cook Inlet, Alaska by the Alaska Board of Fisheries due to inadequate information regarding the biology and stock status of shrimp in Cook Inlet waters (Beverage, 1998). Emergency Orders (AK Rule 2-S-H-11-96 and AK Rule 5 AAC 31.390; AK Dept. of Fish & Game, 1998) were issued for Inner Cook Inlet and Outer Cook Inlet in 1996 and 1997, respectively. A previous rule prohibiting shrimp harvesting in Inner Cook Inlet dates back to 1988. There is currently no evidence that these orders will be lifted in the near future. Therefore, human health effects from exposure to commercial shrimp harvests were not analyzed for Cook Inlet, Alaska SBF-cuttings discharges.

Exhibit 5-4. Arithmetically-Averaged Concentration Data



Regression Output:		Regression Equation:	x (m) (distance)	y (mg/l) (conc.)	Impact Area
X Coefficient(s)	-1.5267	y=1.5267*x+14.7567			
Std Err of Coef:	0.350		8	100,000	0.0002
Constant:	14.7567		38	10,000	0.004
Std Err of Y Est:	1.350		171	1,000	0.1
R Squared:	0.679		772	100	1.9
No. of observations:	11		3,490	10	38
Degrees of freedom:	9		15,768	1	781

5.3.3 *Offshore California*

The concentrations of pollutants in shrimp tissue are presented in Appendix G, Exhibits G-5 and G-6 for offshore California model wells using the current technology and discharge option, respectively. Only shallow water development model wells are considered for shrimp impact analysis because shrimp are harvested mainly from waters potentially affected by shallow water wells and there are no exploration wells in offshore California. The calculations of the sediment pollutant concentrations for offshore California SBF-cuttings discharges are presented in Appendix F.

5.4 Noncarcinogenic and Carcinogenic Risk - Recreational Fisheries

The concentration of pollutants in finfish tissue is used to calculate the risk of noncarcinogenic and carcinogenic (arsenic only) risk from ingestion of recreationally-caught fish. For this analysis, the 99^{th} percentile intake rate of 177 g/day (uncooked basis) is used as the exposure for high-end seafood consumers in the general adult population (SAIC, 1998). This analysis is a worst case scenario because the seafood consumed is assumed to consist only of contaminated finfish.

For noncarcinogenic risk evaluation, the tissue pollutant concentration (mg/kg) is multiplied by the consumption rate (mg/kg/day) for a 70 kg individual. This value is compared to the oral reference dose (RfD) to determine the hazard quotient (HQ) for each pollutant in accordance with the following equations:

$$HQ = CDI / RfD$$

where

HQ = hazard quotient (unitless)
CDI = chronic daily intake (mg/kg/day)
RfD = reference dose (mg/kg/day)

and

$$CDI = (IR * TPC) / BW$$

where

IR = intake rate (0.177 kg/day)
TPC = tissue pollutant concentration (mg/kg)
BW = body weight (70 kg)

The RfD is based on the assumption that thresholds exist for certain toxic effects to occur. These thresholds are estimates of a daily exposure to humans that is likely to be without an appreciable risk of deleterious effects during a lifetime. Therefore, if the hazard quotient is less than or equal to one, toxic effects are considered unlikely to occur. The oral RfDs used in this analysis are from EPA's Integrated Risk Information System (IRIS) database (EPA, 1998c) and are summarized in Exhibit 5-5. For those pollutants without a published oral RfD, no hazard quotient is calculated.

Exhibit 5-5. Oral Reference Doses and Slope Factors

Pollutant	Oral RfD (mg/kg-day)	Slope Factor $(mg/kg\text{-}day)^{-1}$ (a)
Napththalene	2.00e-02	NA
Fluorene	4.00e-02	NA
Phenol	6.00e-01	NA
Cadmium	1.00e-03	NA
Mercury	3.00e-04	NA
Antimony	4.00e-04	NA
Arsenic	3.00e-04	1.50e+00
Chromium	3.00e-03	NA
Nickel	2.00e-02	NA
Selenium	5.00e-03	NA
Silver	5.00e-03	NA
Thallium	8.00e-05	NA
Zinc	3.00e-01	NA
Barium	7.00e-02	NA

(a) NA indicates that a slope factor is not available for that pollutant; there are no slope factors for specific SBF compounds.

Source: EPA, 1998b; Integrated Risk Information System (IRIS).

To calculate the carcinogenic risks, the slope factor as provided by IRIS is used to estimate the lifetime excess cancer risk that could occur from ingestion of contaminated seafood. The cancer risks are calculated in accordance with the following equations:

CR = CDI * SF

where

CR = cancer risk (unitless)
CDI = chronic daily intake (mg/kg/day)
SF = slope factor $(mg/kg/day)^{-1}$

and

CDI = (IR * TPC * EF * ED) / (BW * AT)

where

IR = intake rate (0.177 kg/day)
TPC = tissue pollutant concentration (mg/kg)
EF = exposure frequency (365 days/yr)
ED = exposure duration (two exposure durations considered in this analysis: 30 years and 70 years)

BW = body weight (70 kg)
AT = averaging time (70 year lifetime * 365 days/yr)

For this analysis, only arsenic has a slope factor available for estimation of the lifetime excess cancer risk. The risk calculations for arsenic are performed considering a 30-year exposure period and a 70-year exposure period. For the purposes of this analysis, a risk level of 1×10^{-6} is considered to be acceptable.

Exhibit 5-6 presents a summary of the health risks from ingestion of recreationally-caught finfish from around SBF-cuttings discharges under current technology and the discharge option. Although current practice in Cook Inlet, Alaska and offshore California is zero discharge of SBF-cuttings, the current technology analysis is presented for comparison purposes. None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur. Also all of the lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

5.4.1 *Gulf of Mexico*

The noncarcinogenic and carcinogenic health risks for Gulf of Mexico recreational fisheries are presented in Exhibits 5-7 and 5-8 for current technology and the discharge option, respectively. Based on the 99th percentile consumption rate, the hazard quotients for noncarcinogenic risks and the lifetime excess cancer risk estimates for carcinogens (arsenic) are well below the acceptable risk levels adopted by the Agency for this analysis.

5.4.2 *Cook Inlet, Alaska*

The noncarcinogenic and carcinogenic health risks for Cook Inlet, Alaska recreational fisheries are presented in Exhibits 5-9 and 5-10 for the current technology and the discharge option, respectively. Although current practice in Cook Inlet, Alaska is zero discharge of SBF-cuttings, the current technology analysis is presented for comparison purposes. Based on the 99th percentile consumption rate, the hazard quotients for noncarcinogenic risks and the lifetime excess cancer risk estimate for carcinogens (arsenic) are well below the acceptable risk levels adopted by the Agency for this analysis.

Exhibit 5-6. Summary of Finfish Health Risks

Pollutant	Gulf of Mexico		Cook Inlet, Alaska		Offshore California	
	Current Technology	Discharge Option	Current Technology	Discharge Option	Current Technology	Discharge Option
99th Percentile Hazard Quotient (a, b)						
Naphthalene	3.85e-05	2.67e-05	3.91e-05	2.71e-05	3.72e-06	2.58e-06
Fluorene	7.39e-07	5.12e-07	7.50e-07	5.20e-07	7.14e-08	4.95e-07
Phenol	3.60e-13	3.60e-13	3.66e-13	3.66e-13	3.48e-14	3.48e-14
Cadmium	1.86e-06	1.29e-06	1.88e-06	1.31e-06	1.79e-07	1.24e-07
Mercury	7.90e-06	5.50e-06	8.02e-06	5.59e-06	7.63e-07	5.32e-07
Antimony	3.41e-06	2.37e-06	3.46e-06	2.40e-06	3.30e-07	2.29e-07
Arsenic	1.25e-06	8.65e-07	1.27e-06	8.77e-07	1.21e-07	8.35e-08
Chromium	1.04e-05	7.23e-06	1.06e-05	7.33e-06	1.01e-06	6.98e-07
Nickel	3.27e-07	2.27e-07	3.32e-07	2.30e-07	3.16e-08	2.19e-08
Selenium	2.53e-07	1.75e-07	2.57e-07	1.78e-07	2.45e-08	1.69e-08
Silver	1.68e-08	1.16e-08	1.70e-08	1.18e-08	1.62e-09	1.12e-09
Thallium	4.17e-04	2.89e-04	4.23e-04	2.93e-04	4.03e-05	2.79e-05
Zinc	3.09e-08	2.14e-08	3.13e-08	2.17e-08	2.98e-09	2.07e-09
Lifetime Excess Cancer Risk (c, d)						
Arsenic						
30-yr exposure	2.41e-10	1.67e-10	2.44e-10	1.69e-10	2.32e-11	1.61e-11
70-yr exposure	5.61e-10	3.89e-10	5.70e-10	3.95e-10	5.42e-12	3.76e-12

(a) Only pollutants for which there is an oral RfD are presented in this summary table.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) Only pollutants for which there is a slope factor are presented in this summary table.
(d) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Exhibit 5-7. Recreational Finfish Health Risks - Gulf of Mexico, Current Technology

Pollutant	(A) Fish Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcingenic Risk - Arsenic Only:**	
Naphthalene	3.04e-04	7.70e-07	2.00e-02	3.85e-05		
Fluorene	1.17e-05	2.96e-08	4.00e-02	7.39e-07		
Phenanthrene	2.43e-03	6.15e-06	NA			
Phenol	8.55e-11	2.16e-13	6.00e-01	3.60e-13		
Cadmium	7.34e-07	1.86e-09	1.00e-03	1.86e-06		
Mercury	9.37e-07	2.37e-09	3.00e-04	7.90e-06		
Antimony	5.40e-07	1.37e-09	4.00e-04	3.41e-06		
Arsenic	1.48e-07	3.74e-10	3.00e-04	1.25e-06	30 yr: 1.50e+00	2.41e-10
Beryllium	1.26e-06	3.19e-09	NA		70 yr: 1.50e+00	5.61e-10
Chromium	1.24e-05	3.13e-08	3.00e-03	1.04e-05		
Copper	4.02e-07	1.02e-09	NA			
Lead	3.26e-06	8.24e-09	NA			
Nickel	2.59e-06	6.54e-09	2.00e-02	3.27e-07		
Selenium	5.01e-07	1.27e-09	5.00e-03	2.53e-07		
Silver	3.32e-08	8.39e-11	5.00e-03	1.68e-08		
Thallium	1.32e-05	3.34e-08	8.00e-05	4.17e-04		
Zinc	3.66e-06	9.26e-09	3.00e-01	3.09e-08		
Aluminum	1.99e-01	5.02e-04	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * 0.177 (kg/day) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

Exhibit 5-8. Recreational Finfish Health Risks - Gulf of Mexico, Discharge Option

Pollutant	(A) Fish Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcingenic Risk - Arsenic Only:**	
Naphthalene	2.11e-04	5.34e-07	2.00e-02	2.67e-05		
Fluorene	8.11e-06	2.05e-08	4.00e-02	5.12e-07		
Phenanthrene	1.69e-03	4.26e-06	NA			
Phenol	8.55e-11	2.16e-13	6.00e-01	3.60e-13		
Cadmium	5.09e-07	1.29e-09	1.00e-03	1.29e-06		
Mercury	6.53e-07	1.65e-09	3.00e-04	5.50e-06		
Antimony	3.74e-07	9.46e-10	4.00e-04	2.37e-06		
Arsenic	1.03e-07	2.59e-10	3.00e-04	8.65e-07	30 yr: 1.50e+00	1.67e-10
Beryllium	8.74e-07	2.21e-09	NA		70 yr: 1.50e+00	3.89e-10
Chromium	8.57e-06	2.17e-08	3.00e-03	7.23e-06		
Copper	2.79e-07	7.04e-10	NA			
Lead	2.26e-06	5.71e-09	NA			
Nickel	1.79e-06	4.53e-09	2.00e-02	2.27e-07		
Selenium	3.47e-07	8.77e-10	5.00e-03	1.75e-07		
Silver	2.30e-08	5.82e-11	5.00e-03	1.16e-08		
Thallium	9.14e-06	2.31e-08	8.00e-05	2.89e-04		
Zinc	2.54e-06	6.42e-09	3.00e-01	2.14e-08		
Aluminum	1.38e-01	3.48e-04	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * 0.177 (kg/day) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

Exhibit 5-9. Recreational Finfish Health Risks - Cook Inlet, Alaska, Current Technology

Pollutant	(A) Fish Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcingenic Risk - Arsenic Only:**	
Naphthalene	3.09e-04	7.81e-07	2.00e-02	3.91e-05		
Fluorene	1.19e-05	3.00e-08	4.00e-02	7.50e-07		
Phenanthrene	2.47e-03	6.24e-06	NA			
Phenol	8.68e-11	2.19e-13	6.00e-01	3.66e-13		
Cadmium	7.45e-07	1.88e-09	1.00e-03	1.88e-06		
Mercury	9.51e-07	2.40e-09	3.00e-04	8.02e-06		
Antimony	5.48e-07	1.39e-09	4.00e-04	3.46e-06		
Arsenic	1.50e-07	3.80e-10	3.00e-04	1.27e-06	30 yr: 1.50e+00	2.44e-10
Beryllium	1.28e-06	3.23e-09	NA		70 yr: 1.50e+00	5.70e-10
Chromium	1.26e-05	3.17e-08	3.00e-03	1.06e-05		
Copper	4.08e-07	1.03e-09	NA			
Lead	3.31e-06	8.36e-09	NA			
Nickel	2.62e-06	6.63e-09	2.00e-02	3.32e-07		
Selenium	5.08e-07	1.28e-09	5.00e-03	2.57e-07		
Silver	3.37e-08	8.51e-11	5.00e-03	1.70e-08		
Thallium	1.34e-05	3.38e-08	8.00e-05	4.23e-04		
Zinc	3.72e-06	9.39e-09	3.00e-01	3.13e-08		
Aluminum	2.01e-01	5.09e-04	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * 0.177 (kg/day) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

Exhibit 5-10. Recreational Finfish Health Risks - Cook Inlet, Alaska, Discharge Option

Pollutant	(A) Fish Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcingenic Risk - Arsenic Only:**	
Naphthalene	2.14e-04	5.41e-07	2.00e-02	2.71e-05		
Fluorene	8.23e-06	2.08e-08	4.00e-02	5.20e-07		
Phenanthrene	1.71e-03	4.32e-06	NA			
Phenol	8.68e-11	2.19e-13	6.00e-01	3.66e-13		
Cadmium	5.16e-07	1.31e-09	1.00e-03	1.31e-06		
Mercury	6.63e-07	1.68e-09	3.00e-04	5.59e-06		
Antimony	3.80e-07	9.60e-10	4.00e-04	2.40e-06		
Arsenic	1.04e-07	2.63e-10	3.00e-04	8.77e-07	30 yr: 1.50e+00	1.69e-10
Beryllium	8.87e-07	2.24e-09	NA		70 yr: 1.50e+00	3.95e-10
Chromium	8.70e-06	2.20e-08	3.00e-03	7.33e-06		
Copper	2.83e-07	7.15e-10	NA			
Lead	2.29e-06	5.80e-09	NA			
Nickel	1.82e-06	4.60e-09	2.00e-02	2.30e-07		
Selenium	3.52e-07	8.90e-10	5.00e-03	1.78e-07		
Silver	2.33e-08	5.90e-11	5.00e-03	1.18e-08		
Thallium	9.27e-06	2.34e-08	8.00e-05	2.93e-04		
Zinc	2.57e-06	6.51e-09	3.00e-01	2.17e-08		
Aluminum	1.40e-01	3.53e-04	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * 0.177 (kg/day) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

5.4.3 *Offshore California*

The noncarcinogenic and carcinogenic health risks for offshore California recreational fisheries are presented in Exhibits 5-11 and 5-12 for current technology and the discharge option, respectively. Although current practice in offshore California is zero discharge of SBF-cuttings, the current technology analysis is presented for comparison purposes. Based on the 99th percentile consumption rate, the hazard quotients for noncarcinogenic risks and the lifetime excess cancer risk estimate for carcinogens (arsenic) are well below the acceptable risk levels adopted by the Agency for this analysis.

5.5 Noncarcinogenic and Carcinogenic Risk - Commercial Shrimp

To calculate the noncarcinogenic and carcinogenic health risks for commercial shrimp, the methodology is the same as that used for recreational finfish. However, instead of calculating an effective exposure concentration that describes the portion of the water affected within the mixing zone, the exposure is adjusted by the amount of the total commercial shrimp catch affected. This is estimated by prorating the total potential exposure (total catch) by the portion of the total shrimp catch affected by the well type being analyzed. The shrimp catch is assumed to occur evenly over the area occupied by the species harvested. As calculated for the offshore effluent guidelines Environmental Assessment, the total catch is divided by the populated area to yield a catch density in lbs/mi^2 (Avanti Corporation, 1993). This catch density is multiplied by the area affected for each model well under current technology and the discharge option (number of wells * 1.9 km^2) and divided by the total catch to calculate a percent of the catch affected by the SBF-cuttings discharge. Only shallow water model wells are used in this assessment due to the limited shrimp harvesting that occurs in water depths greater than 1,000 feet.

Exhibit 5-13 presents a summary of the health risks from ingestion of commercially-caught shrimp. None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur. Also all of the lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Exhibit 5-11. Recreational Finfish Health Risks - Offshore California, Current Technology

Pollutant	(A) Fish Tissue Concentration (mg/kg)	(B) 99^{th} %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99^{th} %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcinogenic Risk - Arsenic Only:**	
Naphthalene	2.94e-05	7.44e-08	2.00e-02	3.72e-06		
Fluorene	1.13e-06	2.86e-09	4.00e-02	7.14e-08		
Phenanthrene	2.35e-04	5.94e-07	NA			
Phenol	8.26e-12	2.09e-14	6.00e-01	3.48e-14		
Cadmium	7.09e-08	1.79e-10	1.00e-03	1.79e-07		
Mercury	9.06e-08	2.29e-10	3.00e-04	7.63e-07		
Antimony	5.22e-08	1.32e-10	4.00e-04	3.30e-07		
Arsenic	1.43e-08	3.62e-11	3.00e-04	1.21e-07	30 yr: 1.50e+00	2.32e-11
Beryllium	1.22e-07	3.08e-10	NA		70 yr: 1.50e+00	5.42e-12
Chromium	1.20e-06	3.02e-09	3.00e-03	1.01e-06		
Copper	3.88e-08	9.82e-11	NA			
Lead	3.15e-07	7.96e-10	NA			
Nickel	2.50e-07	6.32e-10	2.00e-02	3.16e-08		
Selenium	4.84e-08	1.22e-10	5.00e-03	2.45e-08		
Silver	3.20e-09	8.10e-12	5.00e-03	1.62e-09		
Thallium	1.27e-06	3.22e-09	8.00e-05	4.03e-05		
Zinc	3.54e-07	8.94e-10	3.00e-01	2.98e-09		
Aluminum	1.92e-02	4.85e-05	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * 0.177 (kg/day) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

Exhibit 5-12. Recreational Finfish Health Risks - Offshore California, Discharge Option

Pollutant	(A) Fish Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcinogenic Risk - Arsenic Only:**	
Naphthalene	2.04e-05	5.16e-08	2.00e-02	2.58e-06		
Fluorene	7.83e-07	1.98e-09	4.00e-02	4.95e-07		
Phenanthrene	1.63e-04	4.12e-07	NA			
Phenol	8.26e-12	2.09e-14	6.00e-01	3.48e-14		
Cadmium	4.91e-08	1.24e-10	1.00e-03	1.24e-07		
Mercury	6.31e-08	1.60e-10	3.00e-04	5.32e-07		
Antimony	3.62e-08	9.14e-11	4.00e-04	2.29e-07		
Arsenic	9.91e-09	2.51e-11	3.00e-04	8.35e-08	30 yr: 1.50e+00	1.61e-11
Beryllium	8.44e-08	2.13e-10	NA		70 yr: 1.50e+00	3.76e-12
Chromium	8.28e-07	2.09e-09	3.00e-03	6.98e-07		
Copper	2.69e-08	6.80e-11	NA			
Lead	2.18e-07	5.52e-10	NA			
Nickel	1.73e-07	4.38e-10	2.00e-02	2.19e-08		
Selenium	3.35e-08	8.47e-11	5.00e-03	1.69e-08		
Silver	2.22e-09	5.62e-12	5.00e-03	1.12e-09		
Thallium	8.83e-07	2.23e-09	8.00e-05	2.79e-05		
Zinc	2.45e-07	6.20e-10	3.00e-01	2.07e-09		
Aluminum	1.33e-02	3.36e-05	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * 0.177 (kg/day) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

Exhibit 5-13. Summary of Shrimp Health Risks

Pollutant	Gulf of Mexico				Offshore California	
	Development		Exploratory			
	Current Technology	Discharge Option	Current Technology	Discharge Option	Current Technology	Discharge Option
99th Percentile Hazard Quotient (a)						
Naphthalene	4.71e-06	5.83e-05	5.44e-06	6.51e-06	2.08e-08	1.19e-08
Fluorene	4.64e-08	5.70e-08	5.35e-08	6.43e-08	2.05e-10	1.17e-10
Phenol	5.28e-12	6.53e-12	6.12e-12	7.32e-12	2.34e-14	1.34e-14
Cadmium	2.59e-06	3.19e-06	3.00e-06	3.60e-06	1.15e-08	6.54e-09
Mercury	1.10e-05	1.36e-05	1.28e-07	1.54e-05	4.89e-08	2.79e-08
Antimony	4.78e-06	5.91e-06	5.52e-06	6.62e-06	2.11e-08	1.21e-08
Arsenic	1.74e-06	2.16e-06	2.02e-06	2.42e-06	7.70e-09	4.42e-09
Chromium	1.46e-05	1.80e-05	1.69e-05	2.02e-05	6.44e-08	3.68e-08
Nickel	4.57e-07	5.64e-07	5.28e-07	6.34e-07	2.02e-09	1.16e-09
Selenium	3.54e-07	4.35e-07	4.10e-07	4.92e-07	1.56e-09	8.92e-10
Silver	2.34e-08	2.89e-08	2.72e-08	3.25e-08	1.04e-10	5.93e-11
Thallium	5.83e-04	7.21e-04	6.77e-04	8.09e-04	2.58e-06	1.48e-06
Zinc	4.32e-08	5.33e-08	4.99e-08	6.01e-08	1.91e-10	1.09e-10
Lifetime Excess Cancer Risk (b)						
Arsenic						
30-yr exposure	3.36e-10	4.16e-10	3.89e-10	4.67e-10	1.49e-12	8.52e-13
70-yr exposure	7.84e-10	9.70e-10	9.08e-10	1.09e-10	3.47e-12	1.99e-12

(a) Only pollutants for which there is an oral RfD are presented in this summary table.
(b) Only pollutants for which there is a slope factor are presented in this summary table.

5.5.1 *Gulf of Mexico*

Under the current technology scenario, there are 13 development wells (12 existing and 1 new source) and 7 existing exploratory wells in Gulf of Mexico shallow waters (< 1,000 ft). Under the discharge option, there are 28 (27 existing and 1 new source) development wells and 15 exploratory wells in Gulf of Mexico shallow waters. The catch impacted in the Gulf of Mexico is calculated in Exhibit 5-14.

Exhibit 5-14. Calculation of Shrimp Catch Impacted in the Gulf of Mexico

	Current Technology		Discharge Option	
	Development	**Exploratory**	**Development**	**Exploratory**
Number of Wells	13	7	28	15
Area Impacted (km^2) (1.9 km^2/well)	24.7	13.3	53.2	28.5
Catch Rate (lbs/mi^2) (a)	11,443			
Total Catch Affected (lbs)	65,856	35,461	141,843	75,987
Total Catch (lbs)	172,474,211			
% of Total Catch Affected	0.038%	0.021%	0.082%	0.044%

(a) The catch rate calculation is presented in Appendix A.

These percentages of catch affected are used to adjust the intake calculations assuming that individuals would consume seafood from the entire Gulf harvest and exposure would be proportional to the amount of the total catch affected. The estimated noncarcinogenic and carcinogenic risks are presented in Exhibits 5-15 through 5-18 for Gulf of Mexico commercial shrimp affected by the current technology and the discharge option. Based on the 99th percentile consumption rate of 177 g/day, the hazard quotients for noncarcinogenic risks and the lifetime excess cancer risk estimate for carcinogens (arsenic) are well below the acceptable risk levels adopted by the Agency for this analysis.

5.5.2 *Cook Inlet, Alaska*

As presented in Section 5.3.2, shrimp harvesting by trawling or pot fishing is prohibited in Cook Inlet, Alaska by the Alaska Board of Fisheries due to inadequate information regarding the biology and stock status of shrimp in Cook Inlet waters (Beverage, 1998). Therefore, human health effects from exposure to commercial shrimp harvests were not analyzed for Cook Inlet, Alaska SBF-cuttings discharges.

Exhibit 5-15. Commercial Shrimp Health Risks - Gulf of Mexico, Shallow Water Development Model Well, Current Technology

Pollutant	(A) Shrimp Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcinogenic Risk - Arsenic Only:**	
Naphthalene	9.80e-02	9.42e-08	2.00e-02	4.71e-06		
Fluorene	1.93e-03	1.85e-09	4.00e-02	4.64e-08		
Phenanthrene	1.11e-01	1.07e-07	NA			
Phenol	3.30e-06	3.17e-12	6.00e-01	5.28e-12		
Cadmium	2.70e-03	2.59e-09	1.00e-03	2.59e-06		
Mercury	3.45e-03	3.31e-09	3.00e-04	1.10e-05		
Antimony	1.99e-03	1.91e+09	4.00e-04	4.78e-06		
Arsenic	5.44e-04	5.23e-10	3.00e-04	1.74e-06	30 yr: 1.50e+00	3.36e-10
Beryllium	4.63e-03	4.45e+09	NA		70 yr: 1.50e+00	7.84e-10
Chromium	4.55e-02	4.37e-08	3.00e-03	1.46e-05		
Copper	1.48e-03	1.42e-09	NA			
Lead	1.20e-02	1.15e-08	NA			
Nickel	9.51e-03	9.14e-09	2.00e-02	4.57e-07		
Selenium	1.84e-03	1.77e-09	5.00e-03	3.54e-07		
Silver	1.22e-04	1.17e-10	5.00e-03	2.34e-08		
Thallium	4.85e-02	4.66e-08	8.00e-05	5.83e-04		
Zinc	1.35e-02	1.30e-08	3.00e-01	4.32e-08		
Aluminum	7.30e+02	7.01e-04	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * (0.177 (kg/day) * % of catch affected) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

Exhibit 5-16. Commercial Shrimp Health Risks - Gulf of Mexico, Shallow Water Development Model Well, Discharge Option

Pollutant	(A) Shrimp Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcinogenic Risk - Arsenic Only:**	
Naphthalene	5.62e-01	1.17e-06	2.00e-02	5.83e-05		
Fluorene	1.10e-03	2.28e-09	4.00e-02	5.70e-08		
Phenanthrene	6.38e-02	1.32e-07	NA			
Phenol	1.89e-06	3.92e-12	6.00e-01	6.53e-12		
Cadmium	1.54e-03	3.19e-09	1.00e-03	3.19e-06		
Mercury	1.97e-03	4.08e-09	3.00e-04	1.36e-05		
Antimony	1.40e-03	2.36e-09	4.00e-04	5.91e-06		
Arsenic	3.12e-04	6.47e-10	3.00e-04	2.16e-06	30 yr: 1.50e+00	4.16e-10
Beryllium	2.65e-03	5.49e-09	NA		70 yr: 1.50e+00	9.70e-10
Chromium	2.60e-02	5.39e-08	3.00e-03	1.80e-05		
Copper	8.46e-04	1.75e-09	NA			
Lead	6.86e-03	1.42e-08	NA			
Nickel	5.44e-03	1.13e-08	2.00e-02	5.64e-07		
Selenium	1.05e-03	2.18e-09	5.00e-03	4.35e-07		
Silver	6.98e-05	1.45e-10	5.00e-03	2.89e-08		
Thallium	2.78e-02	5.76e-08	8.00e-05	7.21e-04		
Zinc	7.71e-03	1.60e-08	3.00e-01	5.33e-08		
Aluminum	4.18e+02	8.67e-04	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * (0.177 (kg/day) * % of catch affected) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

Exhibit 5-17. Commercial Shrimp Health Risks - Gulf of Mexico, Shallow Water Exploratory Model Well, Current Technology

Pollutant	(A) Shrimp Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcinogenic Risk - Arsenic Only:**	
Naphthalene	2.05e-01	1.09e-07	2.00e-02	5.44e-06		
Fluorene	4.03e-03	2.14e-09	4.00e-02	5.35e-08		
Phenanthrene	2.33e-01	1.24e-07	NA			
Phenol	6.91e-06	3.67e-12	6.00e-01	6.12e-12		
Cadmium	5.65e-03	3.00e-09	1.00e-03	3.00e-06		
Mercury	7.23e-03	3.84e-09	3.00e-04	1.28e-05		
Antimony	4.16e-03	2.21e-09	4.00e-04	5.52e-06		
Arsenic	1.14e-03	6.05e-10	3.00e-04	2.02e-06	30 yr: 1.50e+00	3.89e-10
Beryllium	9.71e-03	5.16e-09	NA		70 yr: 1.50e+00	9.08e-10
Chromium	9.53e-02	5.06e-08	3.00e-03	1.69e-05		
Copper	3.10e-03	1.65e-09	NA			
Lead	2.51e-02	1.33e-08	NA			
Nickel	1.99e-02	1.06e-08	2.00e-02	5.28e-07		
Selenium	3.86e-03	2.05e-09	5.00e-03	4.10e-07		
Silver	2.56e-04	1.36e-10	5.00e-03	2.72e-08		
Thallium	1.02e-01	5.42e-08	8.00e-05	6.77e-04		
Zinc	2.82e-02	1.50e-08	3.00e-01	4.99e-08		
Aluminum	1.53e+02	8.12e-05	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * (0.177 (kg/day) * % of catch affected) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

Exhibit 5-18. Commercial Shrimp Health Risks - Gulf of Mexico, Shallow Water Exploratory Model Well, Discharge Option

Pollutant	(A) Fish Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcinogenic Risk - Arsenic Only:**	
Naphthalene	1.17e-01	1.30e-07	2.00e-02	6.51e-06		
Fluorene	2.31e-03	2.57e-09	4.00e-02	6.43e-08		
Phenanthrene	1.33e-01	1.48e-07	NA			
Phenol	3.95e-06	4.39e-12	6.00e-01	7.32e-12		
Cadmium	3.24e-03	3.60e-09	1.00e-03	3.60e-06		
Mercury	4.14e-03	4.61e-09	3.00e-04	1.54e-05		
Antimony	2.38e-03	2.65e-09	4.00e-04	6.62e-06		
Arsenic	6.53e-04	7.27e-10	3.00e-04	2.42e-06	30 yr: 1.50e+00	4.67e-10
Beryllium	5.56e-03	6.19e-09	NA		70 yr: 1.50e+00	1.09e-09
Chromium	5.46e-02	6.07e-08	3.00e-03	2.02e-05		
Copper	1.77e-03	1.97e-09	NA			
Lead	1.44e-02	1.60e-08	NA			
Nickel	1.14e-02	1.27e-08	2.00e-02	6.34e-07		
Selenium	2.21e-03	2.46e-09	5.00e-03	4.92e-07		
Silver	1.46e-04	1.62e-10	5.00e-03	3.25e-08		
Thallium	5.82e-02	6.48e-08	8.00e-05	8.09e-04		
Zinc	1.62e-02	1.80e-08	3.00e-01	6.01e-08		
Aluminum	8.76e+02	9.75e-04	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * (0.177 (kg/day) * % of catch affected) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

5.5.3 *Offshore California*

EPA projects that there is one shallow water development model well using SBFs in offshore California. The shrimp catch impacted offshore California is calculated in the following manner:

impact area per well:	1.9 km^2
number of wells:	1 development well
area impacted:	1.9 km^2
total catch:	836,120 lbs
lbs caught/mi^2:	3.17 lbs/mi^2
catch affected:	1.403 lbs
% catch affected:	0.000168%

This percentage of the catch affected is used to adjust the intake calculations assuming that individuals would consume seafood harvested from the entire offshore California shrimp harvesting area and exposure would be proportional to the amount of the total catch affected. The estimated noncarcinogenic and carcinogenic risks are presented in Exhibits 5-19 and 5-20 for the current technology and discharge option. Although the current practice offshore California is zero discharge of SBF-cuttings, the current technology analysis based on 11% retention on cuttings is presented for comparison purposes. Based on the 99th percentile consumption rate, the hazard quotient for noncarcinogenic risks and the lifetime excess cancer risk estimate for carcinogens are both well below the acceptable risk levels adopted by the Agency for this analysis.

Exhibit 5-19. Commercial Shrimp Health Risks - Offshore California, Shallow Water Development Model Well, Current Technology

Pollutant	(A) Shrimp Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Excess Cancer Risk (c)
Noncarcinogenic Risks					**Carcinogenic Risk - Arsenic Only:**	
Naphthalene	9.80e-02	4.16e-10	2.00e-02	2.08e-08		
Fluorene	1.93e-03	8.20e-12	4.00e-02	2.05e-10		
Phenanthrene	1.11e-01	4.72e-10	NA			
Phenol	3.30e-06	1.40e-14	6.00e-01	2.34e-14		
Cadmium	2.70e-03	1.15e-11	1.00e-03	1.15e-08		
Mercury	3.45e-03	1.47e-11	3.00e-04	4.89e-08		
Antimony	1.90e-03	8.45e-12	4.00e-04	2.11e-08		
Arsenic	5.44e-04	2.31e-12	3.00e-04	7.70e-09	30 yr: 1.50e+00	1.49e-12
Beryllium	4.63e-03	1.97e-11	NA		70 yr: 1.50e+00	3.47e-12
Chromium	4.55e-02	1.93e-10	3.00e-03	6.44e-08		
Copper	1.48e-03	6.29e-12	NA			
Lead	1.20e-02	5.10e-11	NA			
Nickel	9.51e-03	4.04e-11	2.00e-02	2.02e-09		
Selenium	1.84e-03	7.82e-12	5.00e-03	1.56e-09		
Silver	1.22e-04	5.18e-13	5.00e-03	1.04e-10		
Thallium	4.85e-02	2.06e-10	8.00e-05	2.58e-06		
Zinc	1.35e-02	5.73e-11	3.00e-01	1.91e-10		
Aluminum	7.30e+02	3.10e-06	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * (0.177 (kg/day) * % of catch affected) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E

Exhibit 5-20. Commercial Shrimp Health Risks - Offshore California, Shallow Water Development Model Well, Discharge Option

Pollutant	(A) Shrimp Tissue Concentration (mg/kg)	(B) 99th %ile Intake (mg/kg-day)	(C) Oral RfD (mg/kg-day) (a)	(D) 99th %ile Hazard Quotient (b)	(E) Slope Factor (mg/kg-day)-1	(F) Lifetime Exces Cancer Risk (c)
Noncarcinogenic Risks					**Carcinogenic Risk - Arsenic Only:**	
Naphthalene	5.62e-02	2.39e-10	2.00e-02	1.19e-08		
Fluorene	1.10e-03	4.67e-12	4.00e-02	1.17e-10		
Phenanthrene	6.38e-02	2.71e-10	NA			
Phenol	1.89e-06	8.03e-15	6.00e-01	1.34e-14		
Cadmium	1.54e-03	6.54e-12	1.00e-03	6.54e-09		
Mercury	1.97e-03	8.37e-12	3.00e-04	2.79e-08		
Antimony	1.14e-03	4.84e-12	4.00e-04	1.21e-08		
Arsenic	3.12e-04	1.33e-12	3.00e-04	4.42e-09	30 yr: 1.50e+00	8.52e-12
Beryllium	2.65e-03	1.13e-11	NA		70 yr: 1.50e+00	1.99e-12
Chromium	2.60e-02	1.10e-10	3.00e-03	3.68e-08		
Copper	8.46e-04	3.59e-12	NA			
Lead	6.86e-03	2.91e-11	NA			
Nickel	5.44e-03	2.31e-11	2.00e-02	1.16e-09		
Selenium	1.05e-03	4.46e-12	5.00e-03	8.92e-10		
Silver	6.98e-05	2.97e-13	5.00e-03	5.93e-11		
Thallium	2.78e-02	1.18e-10	8.00e-05	1.48e-06		
Zinc	7.71e-03	3.28e-11	3.00e-01	1.09e-10		
Aluminum	4.18e+02	1.78e-06	NA			
Barium	0.00e+00	0.00e+00	7.00e-02	0.00e+00		
Iron	0.00e+00	0.00e+00	NA			
Tin	0.00e+00	0.00e+00	NA			
Titanium	0.00e+00	0.00e+00	NA			

(a) NA indicates that an oral RfD is not available; RfDs are not available for specific SBF compounds.
(b) None of the hazard quotients exceed 1. Therefore, toxic effects are not predicted to occur.
(c) The lifetime excess cancer risks are less than 10^{-6} and are, therefore, acceptable.

Table Calculations:

B = A * (0.177 (kg/day) * % of catch affected) / 70 kg
D = B / C
F = B * 30 yrs (or 70 yrs) / 70 (lifetime in yrs) * E